7th Adaptation to Scientific and Technical Progress of Exemptions 8(e), 8(f), 8(g), 8(h), 8(j) and 10(d) of Annex II to Directive 2000/53/EC (ELV)

Report for the European Commission DG Environment under Framework Contract № ENV.C.2/FRA/2011/0020

Authors:

Carl-Otto Gensch, Oeko-Institut

Yifaat Baron, Oeko-Institut

Otmar Deubzer, Fraunhofer Institut IZM

Amended Final Report, 01/07/2015

Report for:

The European Commission

Prepared by:

Oeko-Institut e.V.

Freiburg Head Office

P.O. Box 1771

79017 Freiburg, Germany

Street Address

Merzhauser Str. 173

79100 Freiburg, Germany

Tel.:+49 (0) 761 – 4 52 95-0

Fax +49 (0) 761 – 4 52 95-288

Web: www.oeko.de

Fraunhofer-Institut IZM

Environmental and Reliability Engineering

Gustav-Meyer-Allee 25

13355 Berlin, Germany

Tel.: +49 30 46403-157

Fax: +49 30 46403-131

Web: www.izm.fraunhofer.de

Approved by:

Adrian Gibbs, Eunomia

………………………………………………….

Contact Details

Eunomia Research & Consulting Ltd
37 Queen Square
Bristol
BS1 4QS

United Kingdom

Tel.: +44 (0)117 – 9172250
Fax: +44 (0)8717 – 142942

Web: www.eunomia.co.uk

Disclaimer

Contents

1.0 Background

Directive 2000/53/EC on end-life-vehicles ("ELV" Directive) restricts the use of certain hazardous substances in vehicles. The Directive includes a list of exemptions to these use restrictions, which is adapted regularly to scientific and technical progress according to the respective provisions in the Directive.

Following the requirements of Article 4(2)(a) of Directive 2000/53/EC on end-of-life vehicles, Member States of the European Union have to ensure that materials and components of vehicles put on the market since 1 July 2003 do not contain lead, mercury, hexavalent chromium and cadmium. A limited number of applications exempted from the provision of this article are listed in Annex II to the Directive as well as the scope and the expiry date of the exemption and the labelling requirement according to Article 4(2)(b)(iv)[1] (if applicable).

Based on Article 4(2)(b), Annex II is to be adapted to scientific and technical progress by the Commission on a regular basis. This is done in order to check whether existing exemptions are still justified with regard to the requirements laid down in Article 4(2)(b)(ii), whether additional exemptions have been proposed on the basis of the same article and whether exemptions are no longer justified and need to be deleted from the Annex with regard to Article 4(2)(b)(iii). Furthermore, the adaptation procedure has to – as necessary – establish maximum concentration values up to which the restricted substances shall be tolerated (Article 4(2)(b)(i)) and designate those materials and components that need to be labelled.

With regard to this adaptation, Annex II has already been adapted 6 times (2002, 2005, 2008, 2010, 2011 and 2013)[2].

2.0 Scope

Oeko-Institut e.V., Fraunhofer Institute for Reliability and Microintegration IZM and Eunomia Research & Consulting have been commissioned by the European Commission with technical assistance for the evaluation of selected exemptions of the ELV Directive, with the aim to provide recommendations for a clear and un-ambiguous wording of the reviewed exemptions. The evaluation includes consultation with stakeholders on the possible adaptation of the Annexes and the set-up of a website in order to keep stakeholders informed on the progress of work (http://elv.exemptions.oeko.info/index.php?id=5).

[1] Article 4(2)(b)(iv) provides that designated materials and components of vehicles that can be stripped before further treatment have to be labelled or made identifiable by other appropriate means.

[2] For further information please see: http://ec.europa.eu/environment/waste/elv_index.htm

In the course of the project, a stakeholder consultation was conducted. The consultation was launched, on 9 September 2013, and ran for eight weeks, until 4 November 2013. The exemptions covered in this stakeholder consultation, specified in Table 3-1, were reviewed in agreement with the Commission, in light of the review period specified for these exemptions in Annex II of the ELV Directive. All non-confidential stakeholder comments submitted during the consultation were made available on the EU CIRCABC website (Communication and Information Resource Centre for Administrations, Businesses and Citizens):

> https://circabc.europa.eu (Browse categories > European Commission > Environment > ELV exemptions, at top left, click on "Library").

3.0 Overview

In the course of the project, six existing ELV exemptions were reviewed. The exemptions covered in this project, together with the recommended expiration wording formulation and expiry dates, are summarised in Table 3-1. Please refer to the corresponding sections of this report for more details on the evaluation results and for more background on the rationale behind the recommendations.

Table 3-1: Overview Recommendations and Expiry Date

No.	Current wording	Recommended wording / action	Recommended expiration / review date
8(e)	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead)	Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead)	Review before July 2021
8(f)	Lead in compliant pin connector systems	i) Lead in compliant pin connector systems for vehicles type-approved before 1 January 2017 and spare parts for these vehicles ii) Lead in compliant pin connector systems other than the mating area of vehicle harness connectors for vehicles type-approved after 31 December 2016	Review in 2019

No.	Current wording	Recommended wording / action	Recommended expiration / review date
8(g)	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages	*It is recommended that the Commission cancel Exemption 8(g) or continue the exemption for now, scheduling a further review in 2016}*	n/a
8(h)	Lead in solder to attach heat spreaders to the heat sink in power semiconductor assemblies with a chip size of at least 1 cm^2 of projection area and a nominal current density of at least 1 A/mm^2 of silicon chip area	Lead in solder to attach heat spreaders to the heat sink in power semiconductor assemblies with a chip size of at least 1 cm^2 of projection area and a nominal current density of at least 1 A/mm^2 of silicon chip area	Vehicles type approved before 1 January 2016 and spare parts for these vehicles
8(j)	Lead in solders for soldering in laminated glazing	Lead in solders for soldering in laminated glazing	Vehicles type approved before 1 January 2020 and spare parts for these vehicles
10(d)	Lead in the dielectric ceramic materials of capacitors compensating the temperature-related deviations of sensors in ultrasonic sonar systems	Lead in the dielectric ceramic materials of capacitors compensating the temperature-related deviations of sensors in ultrasonic sonar systems	Vehicles type approved before 1 January 2017 and spare parts for these vehicles

4.0 Exemption 8 (e) “Lead in High Melting Temperature Type Solders”

Abbreviations and Definitions

BGA	Ball grid array
EFTA	European Free Trade Association (member countries being: Iceland, Liechtenstein, Norway, and Switzerland)
HMPS	High melting point solders
PCB	Printed circuit board
PWB	Printed wiring board
SMD	Surface mount device
THP	Through hole packages
TLPS	Transient liquid phase sintering

Declaration

The phrasings and wordings of stakeholders’ explanations and arguments have been adopted from the documents provided by the stakeholders as far as possible. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text.

4.1 Description of Requested Exemption

The current wording of Exemption 8(e) in Annex II of the ELV Directive is

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

The exemption has become due for review in 2014. ACEA et al.[3] and DA5[4,5] requests the continuation of Exemption 8(e).

4.1.1 History of the Exemption

The exemption was included in Annex II of the ELV Directive, when first published in 2000, and has not been changed since then. This exemption is one of the few material-specific exemptions in Annex II of the ELV Directive as it authorizes the use of lead in high-melting point solders (HMPS) without specifying the application in which these solders may be used. In the last review, in 2008/2009, it was discussed, whether the exemption should therefore be restricted, to applications where lead-free alternatives are not available. During that review, a list of applications was compiled, for which the use of lead-containing HMPS is still unavoidable. However, the exemption was not restricted to these applications for various reasons.

One of the objectives of this review is thus to scrutinize the applications identified in the past review, to clarify whether the use of lead-containing HMPS is still unavoidable.

4.1.2 Technical Background

ACEA et al.[6] lists typical types and melting temperatures of solders currently used (as of August 2013) in applications falling under this exemption. As a reference, they also list types and melting temperatures of solders containing less than 85% of lead, which are prohibited for use by the ELV Directive.

---

3 ACEA et al. (2013) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8e_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_e_/acea_clepa_jama_kama_contribution_Ex_8e_20131104.pdf; last accessed 14.02.2014

4 DA5 (2013) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "20131012_Contribution_Die__Attach_5_Exemption_8e_Stakeholder_Consultation_Answers_v1.7.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_e_/20131012_Contribution_Die__Attach_5_Exemption_8e_Stakeholder_Consultation_Answers_v1.7.pdf; last accessed 14.02.2014

5 "DA5" is a five company consortium known as the "Die Attach 5" formed in 2010 to jointly investigate alternatives for high lead solder for attaching die to semiconductor packages during integrated circuit manufacturing, and thereby to seek standardisation and acceptance. The companies involved are Bosch (Division Automotive Electronics), Freescale Semiconductor, Infineon Technologies, NXP Semiconductors and STMicroelectronics. (2013)

6 Op. cit. ACEA et al. (2013)

Table 4-1: Composition and Melting Temperature of Lead Solders

Category	Solder Type	Alloy Composition [wt %]	Melting Temperatures (Solidus Line / Liquidus Line)
Lead-containing Solder	High temperature type lead-containing solder (Falling under exemption of ELV Directive)	Sn-85Pb	226~290 °C
		Sn-90Pb	268~302 °C
		Sn-95Pb	300~314 °C
	Lead-containing solder Use 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

Source: ACEA et al.[7]

According to ACEA et al.[8], HMPS with 85% of lead or more, as exempted, under Exemption 8(f) are used in several applications, typical examples being:

1. Internal electrical interconnections in components;
2. Die attach;
3. Plastic overmoulding;
4. Ceramic ball grid arrays (BGAs);
5. High power applications;
6. Hermetic sealings;

ACEA et al.[9] says the list is not comprehensive and is missing uses such as clip attach, extreme operating conditions, and high reliability applications. These and other examples belong to the categories listed in Table 4-2.

[7] Op. cit. ACEA et al. (2013)

[8] Op. cit. ACEA et al. (2013)

[9] Op. cit. ACEA et al. (2013)

Table 4-2: Intended Uses of Lead HMPS and Examples for Related Products

Intended use	Examples of related products	Reasons for necessity
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.	Resistors, capacitors, chip coil, resistor networks, capacitor networks, power semiconductors, discrete semiconductors, microcomputers, ICs, LSIs, chip EMI, chip beads, chip inductors, chip transformers, etc. (Annex : Fig.1 to 3)	– Stress relaxation characteristic with materials and metal materials at the time of assembly is needed. – 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.*
Solders for mounting electronic components onto sub-assembled module or sub-circuit boards.	Hybrid IC, modules, optical modules, etc. (Annex : Fig.4)	
Solders used as a sealing material between a ceramic package or plug and a metal case	SAW (Surface Acoustic Wave) filter, crystal resonators, crystal oscillators, crystal filters, etc. (Annex : Fig.5)	

Source: ACEA et al.[10]

The DA5[11] stakeholder contribution illustrates a number of specific uses for die attach as indicated in Figure 4-1.

Figure 4-1: Die Attach Applications using HMPS: Power Modules, Smart Power ASICs, Power MOS-FETs & IGBTs in Surface Mound Device (SMD) Packages, Power MOS-FETs & IGBTs in Through-Hole Packages (THT)

Source: DA5[12]*, pictures not to scale*

[10] Op. cit. ACEA et al. (2013)

[11] Op. cit. DA5 (2013)

[12] Op. cit. DA5 (2013)

4.1.3 Amount of Lead Used under the Exemption

The total amount of lead HMPS used worldwide in electrical and electronic applications in the scope of the RoHS and the ELV Directives is around 11,000 t per year.[13] With a lead content of at least 85%, this results in a total lead use of around 9,000 to 10,000 t per year, with the main uses in the electrical and electronic equipment sector, which is in the scope of the RoHS Directive (but falling under the current RoHS exemptions for HMPS).

DA5[14] calculates the total amount of lead HMPS in all applications under the scope of the ELV Directive based on the ACEA calculation in Oeko-Institut[15] and the ACEA vehicle volumes from 2012 in the EU27 + EFTA. The resulting total amount of lead HMPS is 13.4 million x 0.47 g = 6.3 t per year. With a lead content of at least 85%, the amount of lead in these solders is at least 5.4 t per year in the EU27 + EFTA.

4.2 Stakeholders' Justification for the Exemption

4.2.1 General Justification

According to ACEA et al[16], after ELV and RoHS enforcement, industry spent more than 10 years in research for alternative materials, considering the wide range of possibilities such as additive elements and electrically conductive resins. However, for the three intended uses displayed in Table 4-2, an alternative technology with similar ductility and strength as lead is not yet available.

ACEA et al. explain that lead-free solders of metallic systems, as well as electrically conductive adhesive systems that have a solidus line temperature of 250 °C or higher, have problems and thus cannot substitute lead HMP solders. In addition, as a trend of vehicle components, further miniaturization of structures proceeds, which increases the 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 or steering electronic control units etc.) will be largely affected. In addition, after

[13] Deubzer, O. (2007), Explorative Study into the Sustainable Use and Substitution of Soldering Metals in Electronics – Ecological and Economical Consequences of the Ban of Lead in Electronics and Lessons to Be Learned for the Future; PhD thesis TU Delft, The Netherlands, January 2007, ISBN 978-90-5155-031-3, http://repository.tudelft.nl/view/ir/uuid%3Af9a776cf-57c3-4815-a989-fe89ed59046e/; last accessed 20 May 2014

[14] Op. cit. DA5 (2013)

[15] Oeko-Institut (2009) Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e.V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, retrievable rom http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20 November 2011

[16] Op. cit. ACEA et al. (2013)

production technology has been changed, very careful scrutiny is needed to maintain required high quality of components in the process to avoid field-failures.

Table 4-3 lists types and melting temperatures of lead-free solders that are currently (as of August 2013) in use and of which commercial viability is currently being studied.

Table 4-3: Composition and Melting Temperatures of Main Lead-Free Solders

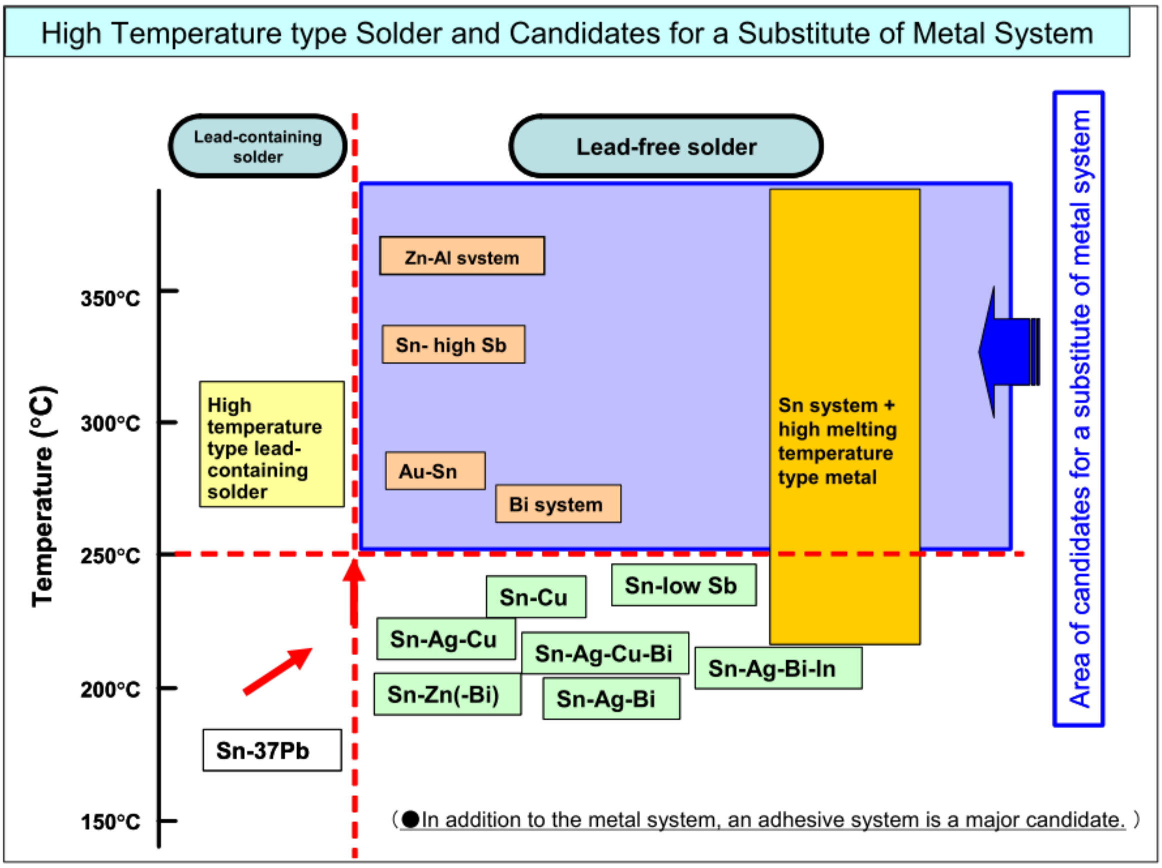
Category	Solder Type	Alloy Composition [wt %]	Melting Temperatures (Solidus Line / Liquidus Line)
Lead-free solders (Solidus Line 250°C or lower)	Sn-Zn(-Bi)	Sn-8.0Zn-3.0Bi	190~197 °C
	Sn-Bi	Sn-58Bi	139 °C
	Sn-Ag-Bi-In	Sn-3.5Ag-0.5Bi-8.0In	196~206 °C
	Sn-Ag-Cu-Bi	Sn96Ag2.5Bi1Cu0.5	213~218 °C
	Sn-Ag-Cu	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

Source: ACEA et al.[17]

Figure 4-2 shows the relationship of types and melting temperatures of lead-containing solder and lead-free solders, based on Table 4-1 and Table 4-3.

[17] Op. cit. ACEA et al. (2013)

Figure 4-2: Relationship Diagram of Solders and Melting Temperatures



Source: ACEA et al.[18]

ACEA et al.[19] argues that 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 HMPS of more than 85% of lead that falls under Exemption 8(f) has gained in importance.

In Table 3-1, ACEA et al.[20] presents advantages and disadvantages of lead-free solders and electrically conductive adhesives with a solidus line temperature of 250°C or higher. Such materials are candidates for the replacement of high temperature type lead-containing solders as listed in Figure 4-2.

---

[18] Op. cit. ACEA et al. (2013)

[19] Op. cit. ACEA et al. (2013)

[20] Op. cit. ACEA et al. (2013)

Table 4-4: Advantages and Disadvantages of High Temperature Lead-Free Solders

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 ･Low strength
	Au-Sn	･Solidus line is high ･Joint operating temperature is comparable with conventional high temperature type solders. ･Strength is high.	･Low ductility ･High cost due to being Au-based
	Sn-high Sb	･Solidus line is high	･Low ductility ･Concern of Sb toxicity ･Joint operating temperature rises higher than conventional high temperature type solders.
	Zn-Al system	･Solidus line is high	･Fragile or low ductility ･Concern of corrosion ･Joint operating temperature rises higher than conventional high temperature type solders.
	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 duration. ･Fragile or low ductility because joint is mainly made by inter-metal compounds.
Electrically conductive adhesive system		･No concern of remelting due to thermal hardening.	･Poor heat conductivity ･Poor electrical conductivity ･Susceptible to humidity ･Difficult to repair

Source: ACEA et al.[21]

ACEA et al.[22] concludes that both lead-free solders of metallic systems and electrically conductive adhesive systems that have solidus line temperature of 250 °C or higher

[21] Op. cit. ACEA et al. (2013)

[22] Op. cit. ACEA et al. (2013)

have problems and thus cannot substitute high temperature type lead-containing solders. As an example for R&D activities related to Exemption 8(e), ACEA et al.[23] refers to the submission of DA5[24], which gives scientific based evidence for the need of high melting point lead containing solder in related automotive applications.

Besides the above general considerations, two specific applications – the use of lead HMPS in hermetic sealings and for die attach – were given specific attention. For hermetic sealings in quartz oscillators, lead-free alternatives had been identified in 2006 already in the RoHS exemption reviews. For die attach, the DA5 submitted separate information explaining the continued need for lead HMPS in this application.

4.2.2 Use of Lead in Hermetic Sealings

For hermetic sealings, Swatch had applied for an exemption under the RoHS Directive in 2006 for the use of lead solder with lower lead content (e.g. Sn90Pb10) in hermetic sealings in quartz crystal resonators, as otherwise Swatch would continue using HMPS with lead content over 95% as exempted both in the RoHS Directive[25] and in Exemption 8(e) in Annex II of the ELV Directive. The request was not granted because lead-free alternatives were available. [26]

ACEA et al. were asked to explain in the stakeholder consultation whether, at least in this application, the use of lead is avoidable in automotive applications. More than eight years have passed since the previous assessment of lead-free alternatives, thereby allowing time to evaluate such alternatives for automotive applications as well as for general electronic equipment.

ACEA et al.[27] claimed that the mentioned application for an exemption from Swatch was for a low melting point lead solder with 37% lead alloy. So indeed there are lead free alternatives for low melting point lead solders. ACEA et al.[28] report that these substitutes are widely used.

However, ACEA et al.[29] understands that there was no discussion about the substitution of lead HMPS, and therefore does not agree with the comment that lead-free solutions were available to replace lead in HMPS in 2006.

---

[23] Op. cit. ACEA et al. (2013)

[24] Op. cit. DA5 (2013)

[25] See Exemption 7a) in Annex III of the RoHS Directive 2011/65/EU

[26] See Oeko-Institut (2006) Gensch, C.; Zangl, S.; Möller, M.; Lohse, J. (Oeko-Institut e.V.); Müller, J.; Schischke, K.; Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, July 2006, pages 83 to 89, „Use of up to 37% of lead in solder alloys .. in quartz movements", retrievable from http://rohs.exemptions.oeko.info/fileadmin/user_upload/rohs_final_report_Oeko_Institut__28-Jul-2006.pdf, accessed 8 May 2014

[27] Op. cit. ACEA et al. (2013)

[28] Op. cit. ACEA et al. (2013)

[29] Op. cit. ACEA et al. (2013)

Up to now, no lead-free materials reach the required performance and reliability, and therefore ACEA et al.[30] concludes that there is no solution available to substitute lead HMPS at this point in time.

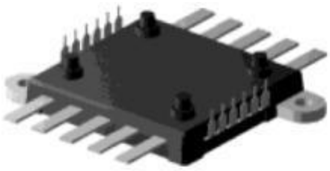
4.2.3 Use of HMPS in Die Attach

DA5[31] explains the main reasons why lead HMPS are used in die attach:

- No re-melting during printed circuit board (PCB) reflow process
- Excellent wettability
- Reliable due to ductility

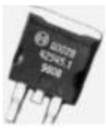
The DA5 have been working on lead-free solutions for die attach. The DA5 evaluations target the following applications:

- Power Modules



- Smart Power ASICs

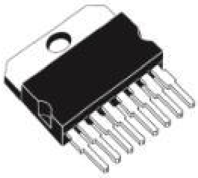
- Power MOS-FETs & IGBTs in Surface Mound Device (SMD) packages



[30] Op. cit. ACEA et al. (2013)

[31] DA5 (2014e) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document “DA5_customer_presentation_070514.pdf”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 5 May 2014

- Power MOS-FETs & IGBTs in Through-Hole packages (THT)



Source of the above four images: DA5[32]; images not to scale

DA5[33] highlights that the different applications have different specifications and may require different lead-free solutions.

DA5[34] claims that no lead-free solutions have yet been identified for any HMP solder die attach applications that currently use lead. The DA5 consortium performed evaluations of different materials together with several material suppliers for the die attach application. This includes four main classes of materials:

- Alternative solders;
- Conductive adhesives;
- Silver-sintering materials; and
- TLPS (transient liquid phase sintering) materials;

[32] DA5 (2014c) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5 Answer 8e ELV Stakeholder Meeting Berlin 09052014 v6.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 16 May 2014

[33] Ibid.

[34] Op. cit. DA5 (2013)

Figure 4-3: Material Classes of Potential Replacements for Lead-Containing HMPS

Source: DA5[35]

DA5[36] states that so far, no material has been identified that fulfils the required properties for a replacement of lead-containing HMPS. These properties are listed as follows:

- Automotive Electronics Council (AEC) reliability specification: AEC-Q100 / AEC-Q101 Grade 0;
- Typical $T_{junction}$ 175 °C; max. up to 200 °C;
- Improvement of thermal/electrical properties needed compared to existing solutions;
- Moisture sensitivity level MSL3 or better for reflow at 260 °C (SMD);
- Wire bonding temperature up to 260 °C;
- Physics of failure understood;

DA5[37] states that the requirements may be slightly different for different applications. DA5[38] gives a detailed description of the requirements for materials and technologies

---

35 Op. cit. DA5 (2013)

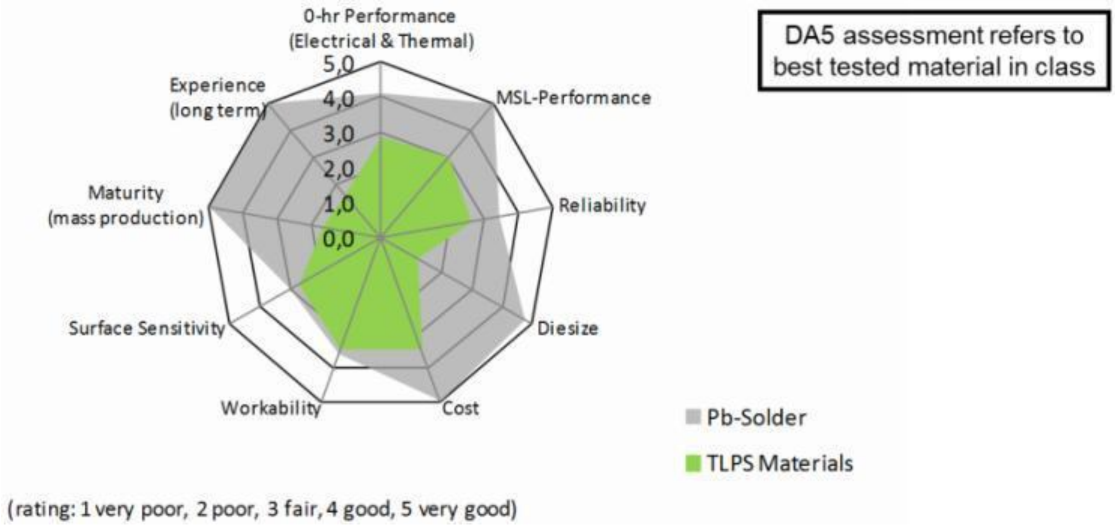
36 Op. cit. DA5 (2013)

37 Op. cit. DA5 (2013)

38 DA5 (2014b) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5_Pb_Free_Die_Attach_Material_Requirements_ver2_2.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 3 April 2014

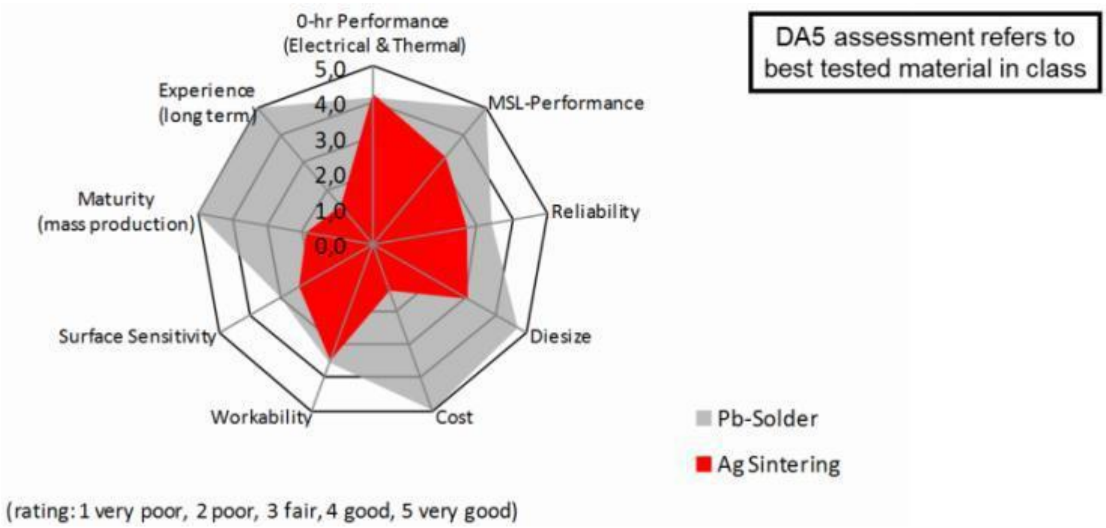
to substitute or eliminate lead-containing HMPS. DA5[39] introduces the evaluation results of the various lead-free materials.

Figure 4-4: Performance of TLPS-Materials vs. Lead HMPS



Source: DA5[40]

Figure 4-5: Performance of Silver Sintering vs. Lead HMPS



Source: DA5[41]

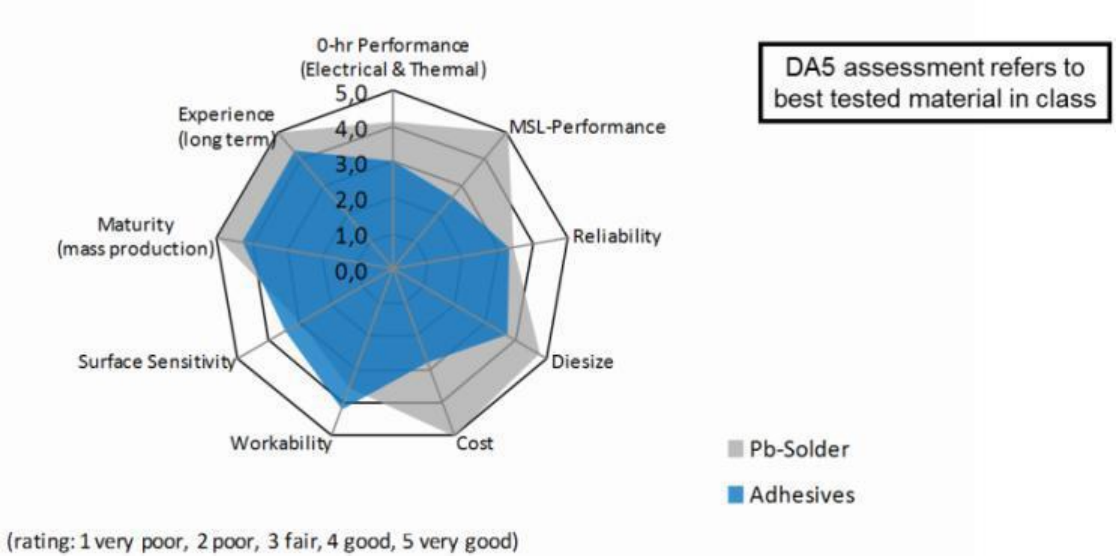
---

[39] Op. cit. DA5 (2014c)

[40] Op. cit. DA5 (2014c)

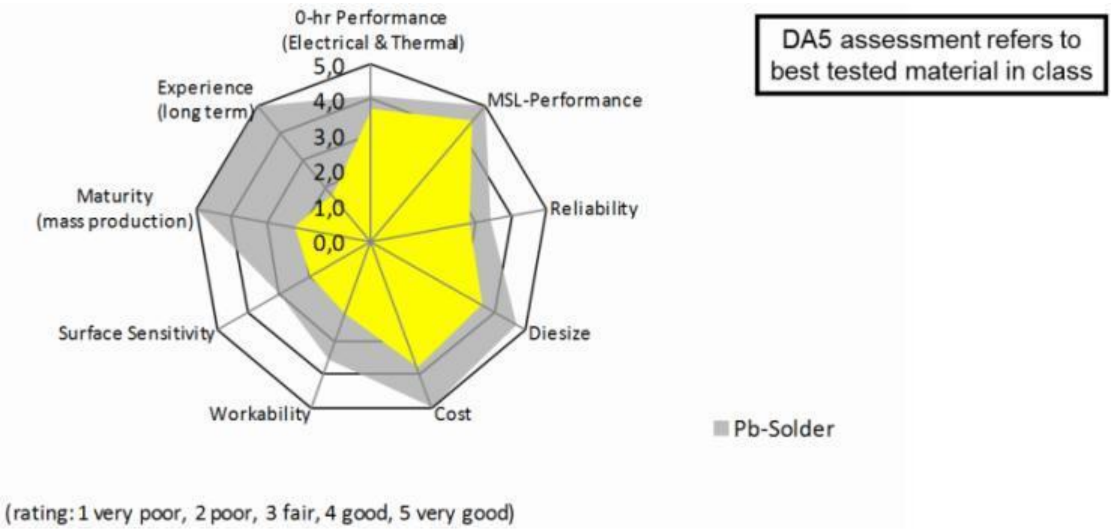
[41] Op. cit. DA5 (2014c)

Figure 4-6: Performance of Conductive Adhesives vs. Lead HMPS



Source: DA5[42]

Figure 4-7: Performance of Lead-free Solders vs. Lead HMPS



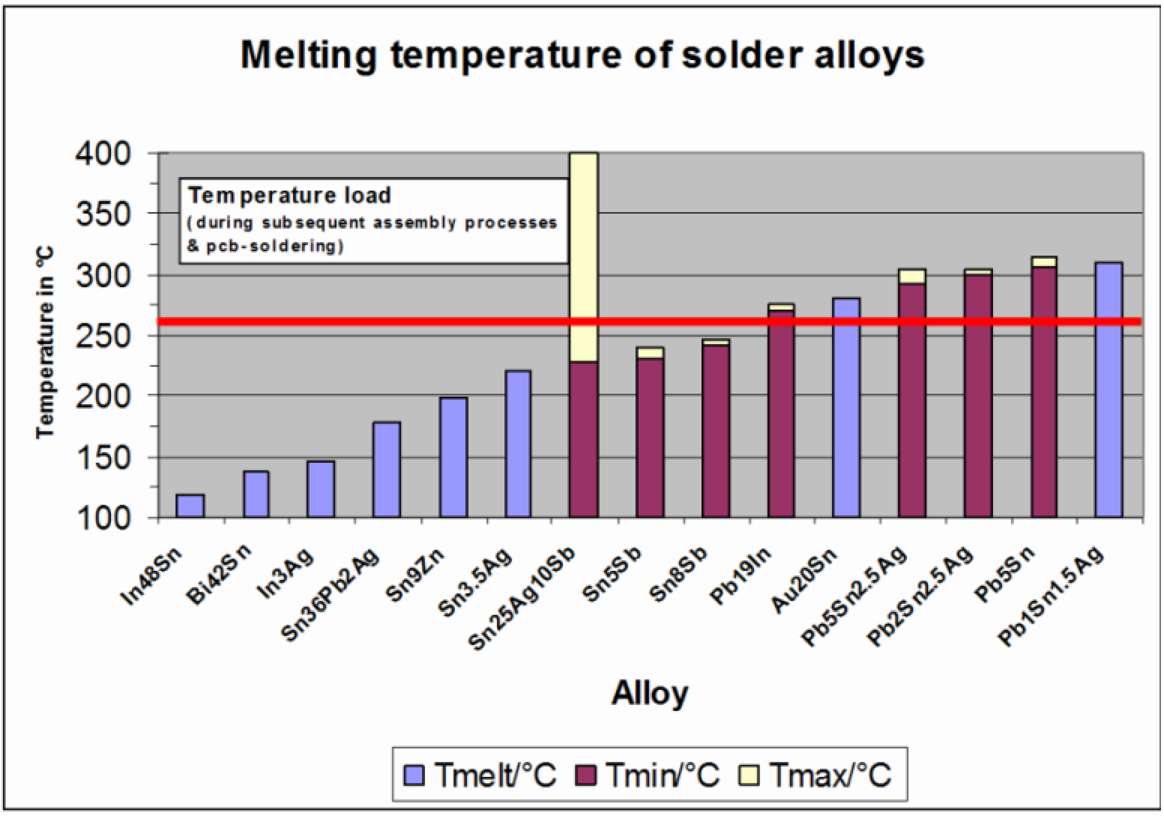
Source: DA5[43]

[42] Op. cit. DA5 (2014c)

[43] Op. cit. DA5 (2014c)

As one of the main obstacles for introducing a lead-containing HMP solder replacement, DA5[44] has identified the combined requirement to survive temperatures during second-level assembly of the package without re-melting on one side and to maintain the performance of a lead-containing HMP solder at the same time. Only few solder alloys with high enough melting point are available. Most of them contain lead, as illustrated in Figure 4-8.

Figure 4-8: Melting Temperatures of Solder Alloys



Source: DA5[45]

In summary of the above information, DA5 2013 claims that alternative materials have not yet been found that can deliver the performance of lead-containing HMP solder. Appendix A.1.0 gives more details of the assessed alternative die attach materials and the evaluation results, provided by DA5.

[44] Op. cit. DA5 (2014c)

[45] Op. cit. DA5 (2014c)

4.3 Critical Review

4.3.1 Use of Conductive Adhesives in Die Attach

DA5 mentions in their contributions that no lead-free solutions are available where lead-containing HMPS are used in die attach. This wording raised the question whether all die attach applications actually use lead-containing HMPS.

DA5[46] confirms that not all semiconductor dies need HMPS as die attach material. Lead-free die attach solutions are available on the market, like silver filled conductive adhesives. Epoxy die attach is a commonly used die attach method also used by the DA5 companies. The DA5 investigations are limited to power devices using high-lead solders for die attach, which have special thermo-mechanical temperature profile requirements to withstand and to transfer heat that is generated during the electrical operation of the circuit. For these power applications, the DA5 could not yet identify a substitute material.

DA5[47] explains that adhesives in general have some favourable properties that make them applicable for lots of applications in industry.

- Adhesives are a solution for packages, which can't withstand the higher soldering temperature (~400°C soldering temperature with HMPS versus ~150 °C glue curing temperature). BGA (ball grid array) packages with organic substrates use adhesives in die attach for example.
- Adhesives are the typical solution for very thin leadframes (~200 µm) due to unacceptable leadframe bending after a high temperature soldering process.
- In general, adhesives have a bigger process window as compared to solder and can be used also for non-metallized chip backsides.

Nevertheless, DA5[48] explains adhesives have severe limitations, esp. in terms of performance, that still justify the use of HMPS for power devices. DA5[49] gives an overview of key performance indicators of high performance adhesives in comparison with HMPS showing significant gaps that are still present with solutions available today:

- Especially for power devices there are major restrictions for the usage of adhesives. The bulk electrical and thermal conductivity of an adhesive is much smaller (<1*106 S/m and max. 25 W/m K) as compared to HMPS

46 DA5 (2014a) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "Questionnaire-2_Exe-8e_DA5_inputs_v3.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 3 April 2014

47 DA5 (2014d) DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "Final-Questionnaire_Exe-8e_DA5_02072014.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 1 June 2014

48 Ibid.

49 Ibid.

(~5*106 S/m and ~50 W/m K). This keeps products that are covered with HMPS today from converting to conductive adhesives.

- Adhesives can only be used for chip thickness > 120 µm due to glue creepage on the side walls of the chips. Due to performance reasons, new chip technologies tend to go for 60 µm or even lower thicknesses
- Also the chip size for adhesive is limited to ~30 mm2 due to the shrinkage of the glue during curing and thermo-mechanical instability. Mechanical strength is lower compared to HMPS (reliability issue).
- Another issue is the sensitivity of glues for humidity. Moisture uptake of adhesives can lead to moisture-induced failure during reflow soldering.
- Adhesives can't be used for products with a high junction temperature (> 175 °C). At such high temperatures, the organic components of the glue tend to degrade.
- Conductive adhesives are based on silver in an organic matrix. Silver tends to migrate under voltage and humidity. Higher power density increases the risk of electro-migration.

DA5[50] explains that the electronics industry naturally works towards eliminating lead HMPS because alternatives (e.g. conductive adhesive) are typically easier to manufacture with. Lead HMPS are only used when no other options are available that enable the required product reliability and functionality.

4.3.2 Substitution and Elimination of Lead in Hermetic Sealings

4.3.2.1 Relevance of the 2006 Swatch Exemption Review

ACEA et al. claim that the Swatch exemption request described in Section 4.2.2 on page 12 did not address the replacement of lead HMPS, but the replacement of lead solder with 37% lead content only, and therefore does not prove that lead-free alternatives have been available for lead HMPS.

This statement is correct in so far that Swatch had not used lead HMPS before 2006 in their watches, but a Sn95Pb5 alloy with 5% of lead. As this alloy was not RoHS compliant, Swatch had applied for an exemption allowing the continued use of this alloy. Swatch otherwise would have changed to the exempted lead HMPS with at least 85% of lead content. The consultants, however, were able to show that the market at that time had already offered lead-free solutions, and consequently the Commission did not grant the requested exemption.[51] The main argument behind Swatch's

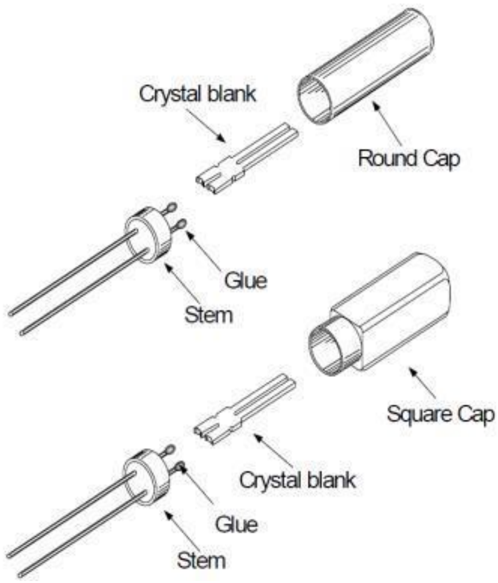
[50] Ibid.

[51] See Oeko-Institut (2006) Gensch, C.; Zangl, S.; Möller, M.; Lohse, J. (Oeko-Institut e.V.); Müller, J.; Schischke, K.; Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, July 2006, pages 83 to 89, „Use of up to 37% of lead in solder alloys .. in quartz movements", retrievable from http://rohs.exemptions.oeko.info/fileadmin/user_upload/rohs_final_report_Oeko_Institut__28-Jul-2006.pdf, accessed 8 May 2014

exemption request regarded the risk for whisker growth, which is also a main motivation for the exemption request of ACEA et al. Being aware of differences in the requirements for RoHS and ELV applications, ACEA et al. was nevertheless asked to explain whether such lead-free solutions were tested for automotive applications.

ACEA et al.[52] explains that the low melting low lead content Sn90Pb10 applied to the seal ring of a cylindrical housing with metal cap until 2006 was used for through hole mounted packages as illustrated in Figure 4-9.

Figure 4-9: Quartz Crystal Resonator with Metal Cap



Source: ACEA et al.[53]

According to ACEA et al.[54], these packages were not suitable for reflow soldering processes and thus do not require HMPS from the process point of view, but adding small amounts of lead is performed purely to suppress tin whisker growth.

Today, according to ACEA et al.[55], this low lead containing alloy is usually replaced by lead-free alloys. However, it has been shown in the past 10 years that this lead free sealing still bears the risk of tin whisker growth. Tin whisker growth up to electrical short circuits have been found in “lead free” sealed crystals of all manufacturers, not only Swatch. Ignoring the risk of whisker growth with its consequences, i.e. reduced reliability, there are indeed lead free alternatives available and widely used for

---

[52] ACEA et al. (2014a) ACEA, CLEPA, JAMA, KAMA stakeholder document “ACEA CLEPA JAMA and KAMA Answers_Questionnaire-2_Exe-8e_20140404”, received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 4 April February 2014

[53] Ibid.

[54] Ibid.

[55] Ibid.

cylinder type crystals, which undergo manual soldering as were subject to the Swatch exemption request. ACEA et al.[56] concludes that there are indeed lead free alternatives which are industry standard, even though the risk of tin whisker growth remains.

Lead containing HMPS, according to ACEA et al.[57], are however needed for applications that require hermetic sealings (i.e. on cylinder crystals) which undergo reflow soldering processes. Such hermetically sealed reflow packages require a substantially higher melting point solder for the sealing so that the sealing can withstand the reflow solder process without remelting and thus possibly affecting the vacuum. Currently, only lead HMPS offer the combination of high melting points and reliable sealing properties. Hermetically sealed packages consisting of a metal case and a ceramic package or plug therefore require lead HMP solders if these packages undergo subsequent reflow soldering processes. An example might be where the metal can body (square package) is attached to the printed circuit board using SMD technologies (Swatch), or where the cylinder is sealed to a lead-frame, and the following second reflow process contacting the moulded cylinder to the final PWB [printed wiring board] using SMD technologies. Moulding of the cylinder into a plastic mould is needed to allow this part to be handled in modern SMD production lines. Therefore, the multiple reflow process on the hermetically sealed cylinder cannot be avoided and the lead HMPS cannot be replaced.

4.3.2.2 Elimination of Lead

ACEA et al. had claimed that lead can neither be reliably substituted nor eliminated in this application. However, a short internet investigation indicated that lead-free solutions are offered for hermetic sealings in oscillators[58], even with qualifications for automotive applications. Ceramic packages for oscillators are alternative technologies that are available for automotive applications as well[59].

ACEA et al. were asked to comment on these findings. ACEA et al.[60] explained that alternative surface mount devices (SMD) are available like ceramic packages with metal case (or lid) with a ceramic lid instead of a plastic moulded metal cylinder. Such packages consisting of a ceramic body and a ceramic lid do not use lead HMPS but seam welding as sealing method. They are partly used for automotive applications.

---

[56] Ibid.

[57] Ibid.

[58] For product information, please see http://www5.epsondevice.com/en/quartz/product/osc/spxo/index.html; an example for a lead-free oscillator for automotive can be found here: http://www.epsondevice.com/docs/qd/en/DownloadServlet?id=ID000933

[59] For product information, please see http://www.microcrystal.com/index.php/applications/automotiveapplications

[60] Op. cit. ACEA et al. (2014a)

However, it is not possible to substitute all the automotive applications only by this type of ceramic package.

The main reasons, according to ACEA et al.[61], are:

- The referred type of package is designed for small size applications. Mounting methods and mechanical performance are vastly different.
- Ceramic package crystals have vastly different characteristics and specs compared to cylindrical or cubical type metal can crystals (plastic moulded or blank) due to mechanical constraints of the packages, so that they cannot easily be replaced by each other and cannot cover all frequencies which cylindrical or cubical type metal can crystals can support.

ACEA et al.[62] states that ceramic crystals might not work in some of today's applications as they are not compatible with the latest low power ICs (integrated circuits). Furthermore, there is a wide use of cylindrical or cubical type metal can crystals (plastic moulded or blank) in the electronic market (e.g. automotive, mobile phone, metering, computer applications etc.), which (even assuming electrical compatibility) cannot be replaced by ceramic packaged devices without major redesigns requiring extensive, time consuming and expensive testing as well as potential changes in specification.

4.3.3 Conclusions

4.3.3.1 Unavoidable Use of Lead in Die Attach

The DA5 evaluated several lead-free materials for lead-free die attach. However, some of the evaluation criteria which the DA5 apply are, in the consultants view, questionable in light of the requirements for exemptions according to Art. 4(2)(b)(ii):

- *"Improvement of thermal/electrical properties needed compared to existing solutions"* (as listed underneath Figure 4-3 in Section 4.2.3);
- The *'cost'* and *'long-term experience'* criteria parameters used within the comparisons of various solutions (see Figure 4-4 through Figure 4-7 in Section 4.2.3).

As far as the improvement of thermal and electrical properties means that lead-free solutions must <u>'exceed'</u> the performance of the existing lead HMPS solutions, such a demand presents an unnecessary barrier to avoid lead. Materials and technologies substituting or eliminating the use of lead must be 'sufficient' in their performance for the application in question, but it is not necessary to exceed the performance of existing solutions based on lead. As the DA5 compare the performance of lead-free materials and technologies to that of lead HMPS, e.g. in Figure 4-7 on page 17, it can

[61] Op. cit. ACEA et al. (2014a)

[62] Op. cit. ACEA et al. (2014a)

be plausibly assumed that the improvement clause is related to existing lead-free materials and technologies and not to the lead HMPS.

Based on the exemption review practices applied in previous reviews, cost criteria are not in line with Art. 4(2)(b)(ii) and therefore cannot be the basis for the continuation of an exemption. Higher costs of a substitute or an elimination technology compared to the standard lead technology therefore do not justify an exemption.

Long-term experience is a valid criterion when comparing lead-free solutions among each other. Requiring long term experiences from lead-free materials or technologies, to a degree similar to the material to be substituted, is a barrier against innovations that could otherwise enable the substitution or elimination of lead. Lead-free solutions are often new materials and therefore can never provide the long-term experience of a standard solution that has been applied for decades already.

The evaluations of lead-free materials and technologies displayed in Figure 4-4 through Figure 4-7 must therefore be evaluated without taking into consideration the above excluded evaluation criteria. However, in spite of this, the DA5 assessments still plausibly indicate that lead cannot be substituted or eliminated yet. The DA5 focused their work on die attach in the power semiconductor area. The use of lead is still unavoidable and the continuation of Exemption 8(e) for power semiconductor applications would therefore be in line with Art. 4(2)(b)(ii).

4.3.3.2 Use of Conductive Adhesives in Die Attach

As explained in Section 4.3.1 on page 19, silver filled conductive adhesives are a commonly used die attach material also used by the DA5 companies.

As exemptions should only cover applications where the use of a restricted substance is unavoidable, the applications where conductive adhesives can be used must be clearly defined and demarcated from those where the use of lead HMPS is still unavoidable in order to justify the continuation of Exemption 8(e) for die attach in line with Art. 4(2)(b)(ii).

Conductive adhesives are used for packages, which cannot withstand the high process temperatures related to the use of lead HMPS because they contain organic substrates, e.g. BGA packages with organic substrates and very thin lead-frames[63]. Furthermore, different from lead HMPS, conductive adhesives can be applied in die attach applications with unmetallised backsides.

In these applications, lead HMPS cannot be applied for technical reasons. In the consultants' opinion it is not necessary to exclude applications from the scope of Exemption 8(e) where lead HMPS technically cannot be used.

[63] The word "lead" in lead-frame is not related to the substance lead (Pb).

4.3.3.3 Use of Lead in Hermetic Sealings

Epson, the manufacturer of the above referenced lead-free crystal oscillators, was asked for its position on the status of lead-free hermetic sealings. Epson[64] provides a detailed description of the situation that complements and substantiates the information provided by ACEA et al. The Epson contribution can be found in Appendix A.2.0.

ACEA et al. and Epson plausibly explain why lead technically can neither be substituted in hermetic sealings of quartz crystal oscillators with metal caps, nor be eliminated by the use of ceramic packages.[65] The use of lead therefore is still unavoidable and the continuation of Exemption 8(e) would be justified according to Art. 4(2)(b)(ii).

Based on the information submitted, lead-free alternatives for other uses of lead HMPS are not available.

4.4 Recommendation

Based on the information submitted, the use of lead in high melting point solders in Exemption 8(e) is still unavoidable. The continuation of Exemption 8(e) would therefore be in line with the requirements of Art. 4(2)(b)(ii) for exemptions. The consultants therefore recommend the continuation of Exemption 8(e) with the current scope and wording. The consultants additionally recommend to review Exemption 8(e) in parallel to the review of Exemption 7(a) in Annex III of the RoHS Directive. This would provide broader insights into the scientific and technical status of the exemption, and an identical wording of the new exemption as far as the different requirements of applications under the RoHS and the ELV Directive would allow this.

The consultants recommend reviewing the exemption by 2021 at the latest. In July 2021, RoHS Exemption 7(a) is expected to expire for all categories of electrical and electronic equipment in the scope of the RoHS Directive, provided that it has not yet been repealed by then, and provided that stakeholders apply in due time for the continuation of the exemption beyond July 2021. A review of ELV Exemption 8(e) before July 2021 could provide for a broader stakeholder involvement, allowing more comprehensive and detailed insights into the actual status of lead-free solutions for the substitution and elimination of lead in high melting point solders.

A review before July 2021 would mean that the next review may take place approximately seven years from this current review. This period between exemption reviews coincides with the maximum validity periods of exemptions for electrical and electronic equipment with long redesign cycles and complex product structures, i.e. medical equipment and monitoring and control instruments. These criteria apply to

---

[64] Epson Europe Electronics GmbH, stakeholder document “ELV 8e Epson.doc”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Stefan Hartmann, Epson, on 4 July 2014

[65] For details see section 4.3.2 on page 18 and Appendix A.2.0.

vehicles as well. A seven year review period would thus approach the exemption review practices of the ELV Directive and of the RoHS Directive.

Based on the above considerations, the consultants recommend the following wording and review period for ELV Exemption 8(e):

Materials and components	Scope and expiry date of the exemption
Lead in high melting temperature type solders (i.e. lead-based alloys containing 85% by weight or more lead)	*Review before July 2021*

In case 2021 is considered by the Commission to be too late for a review date for ELV Exemption 8(e), it would have been beneficial to coordinate the next review with the possible earlier review of RoHS Exemption 7(a) expected to take place before July 2016 (provided that stakeholders apply for the continuation beyond 2016). As under the RoHS Directive, an application for renewal would have to be submitted at least 18 months ahead of the expiration date, after which a review would take place; such a review would at least in part be expected to be carried out in 2015. In the consultants' opinion, this is too close to the current review to assume that significant progress could be achieved within this period for automobile industry applications.

4.5 References Exemption 8(e)

ACEA et al. 2013 — ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8e_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_e_/acea_clepa_jama_kama_contribution_Ex_8e_20131104.pdf; last accessed 14 February 2014

ACEA et al. 2014a — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA and KAMA Answers_Questionnaire-2_Exe-8e_20140404", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 4 April February 2014

DA5 2013 — DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "20131012_Contribution_Die__Attach_5_Exemption_8e_Stakeholder_Consultation_Answers_v1.7.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_e_/20131012_Contribution_Die__Attach_5_Exemption_8e_Stakeholder_Consultation_Answers_v1.7.pdf; last accessed 14 February 2014

DA5 2014a	DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "Questionnaire-2_Exe-8e_DA5_inputs_v3.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 3 April 2014
DA5 2014b	DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5_Pb_Free_Die_Attach_Material_Requirements_ver2_2.pdf" , sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 3 April 2014
DA5 2014c	DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5 Answer 8e ELV Stakeholder Meeting Berlin 09052014 v6.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 16 May 2014
DA5 2014d	DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "Final-Questionnaire_Exe-8e_DA5_02072014.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 1 June 2014
DA5 2014e	DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5_customer_presentation_070514.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 5 May 2014
Deubzer 2007	Deubzer, O.; Explorative Study into the Sustainable Use and Substitution of Soldering Metals in Electronics – Ecological and Economical Consequences of the Ban of Lead in Electronics and Lessons to Be Learned for the Future; PhD thesis TU Delft, The Netherlands, January 2007, ISBN 978-90-5155-031-3, http://repository.tudelft.nl/view/ir/uuid%3Af9a776cf-57c3-4815-a989-fe89ed59046e/

; last accessed 1 February 2013

Epson 2014	Epson Europe Electronics GmbH, stakeholder document "ELV 8e Epson.doc", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Stefan Hartmann, Epson, on 4 July 2014
Oeko-Institut 2009	Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e. V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, retrievable from http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20 November 2011

5.0 Exemption 8(f) "Lead in Compliant Pin Connector Systems"

Abbreviations and Definitions

CoPiCS	Compliant pin connector systems
ECU	Engine control unit
FMEA	Failure mode and effect analysis
OEM	Original equipment manufacturer
OSP	Organic surface protection
PCB	Printed circuit board
PTH	Plated through holes

Declaration

The phrasings and wordings of stakeholders' explanations and arguments have been adopted from the documents provided by the stakeholders as far as possible. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text.

5.1 Description of Requested Exemption

ACEA et al.[66] requests the continuation of Exemption 8(f) in Annex II of the ELV Directive, i.e. relating to:

> *Lead in compliant pin connector systems.*

5.1.1 History of the Exemption

Annex II of the ELV Directive was reviewed in 2009. At that time it was assessed that lead-free solutions were not yet available for compliant pin connector systems (CoPiCS), even though the substitution of lead in CoPiCS had been proved to be viable in CoPiCS for applications in electrical and electronic equipment under the scope of

---

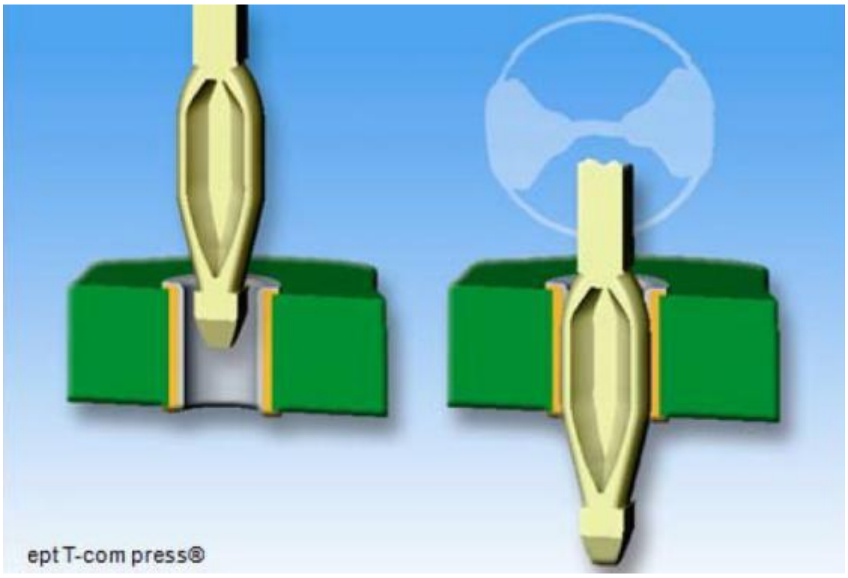
[66] ACEA et al. (2013b) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8f_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_f_/acea_clepa_jama_kama_contribution_Ex_8f_20131104.pdf; last accessed 27 December 2013

the Directive 2002/95/EC (RoHS 1)[67]. The main difference was that automotive CoPiCS use insertion forces in the range of 120 to 150 N, while for CoPiCS used in EEE in the scope of RoHS, 20 to 50 N are sufficient.[68] As the stakeholders stated in 2009 that lead-free alternatives were under development, the exemption was scheduled for review in 2014, to adapt it to the scientific and technical progress.

5.1.2 Technical Background

ACEA et al.[69] explains that compliant pin connector or press-fit connector systems provide a method of attachment and electrical contact between a connector and printed circuit board (PCB), which does not require a soldering operation. The pin contacts are inserted into 'plated through holes' (PTH) in the PCB (see Figure 5-1) and the mechanical design of the pin provides reliable electrical contact.

Figure 5-1: Assembly of a Press Fit Pin Connector into a Board Structure



Source: ACEA et al.[70]

---

[67] For details see pages 140 to 152: Oeko-Institut (2009) Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e.V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, retrievable from http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20.11.2011

[68] For details see pages 109-118: Oeko-Institut (2010) Zangl, S.; Hendel, M.; Blepp, M.; Liu, R.; Gensch, C. (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, retrievable from https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 5.09.2013

[69] Op. cit. ACEA et al. (2013b)

[70] Op. cit. ACEA et al. (2013b)

According to ACEA et al.[71], the compliant pins must be sufficiently flexible to deform as they are inserted into the holes without an excessively high force that might damage the plating in the holes. The press fit technology thus saves solder material and energy.

The tin-lead plating on the pins contains about 5%-10% lead and is only about 0.25-1.5 microns thick. Tin-lead plating covers only the termination portion of the contact, which includes the compliant section, which is about 2-7 mm long. Such connectors are used on printed circuit board assemblies contained in most automotive applications.[72]

ACEA et al.[73] claims that the tin-lead plating is required to:

- Provide lubrication while the pins are inserted in order to reduce the insertion force, thus avoiding damage of the PTH, which ensures the required reliability of the contact;
- Ensure good electrical contact once the pin has been inserted;
- Prevent whisker growth;
- Additionally, ACEA et al.[74] highlights that CoPiCS are widely used in safety-related parts like anti-lock braking systems or airbag systems. In case of failure, human life is directly endangered.[75]

[71] Op. cit. ACEA et al. (2013b)

[72] Op. cit. ACEA et al. (2013b)

[73] Op. cit. ACEA et al. (2013b)

[74] Op. cit. ACEA et al. (2013b)

[75] For more details on the technical background see Oeko-Institut (2009), pages 140-152, and Oeko-Institut (2010), pages 109-118

5.1.3 Amount of Lead Used under the Exemption

ACEA et al.[76] bases an estimation of lead use under this exemption on the assumptions listed in Table 5-1.

Table 5-1: Basic Assumptions for the Calculation of Lead Use under Exemption 8(f)

Value	Unit	Description
3.2	mm	Circumference of pin
7.0	mm	Length of surface
0.8	µm	Thickness of layer
7%	Lead portion of layer	
0.0012544	mm^3	Volume of Pb per pin
0.011342	g/mm^3	Specific mass density of lead
14.2274	µg	Weight of lead per pin
100	Pin/ECU (engine control unit)	Number of pins per ECU
10	ECU/Car	Number of ECUs per Car
71,490,000	Cars	Cars worldwide*
13,430,000	Cars	Cars in Europe*

**Note: Given the context of the table in the original document, the consultants understand the data provided for the number of cars in the EU and worldwide to regard annual quantities of cars placed on the respective markets.*

Source: ACEA et al.[77]

[76] Op. cit. ACEA et al. (2013b)

[77] Op. cit. ACEA et al. (2013b)

Based on the above assumptions, ACEA et al.[78] calculates the total, worldwide amount of lead used in CoPiCS to be 1.0 t per annum of lead worldwide, and around 0.2 t per annum in Europe.

ACEA et al.[79] admits that this is much less than the 0.8 t per annum ACEA et al. had estimated for Europe in the 2009 review. ACEA et al.[80] attributes this to the lower amount of lead with thinner platings that have been introduced during the last years.

5.2 Stakeholders' Justification for Exemption

5.2.1 Elimination of Lead

In principle, CoPICS could be replaced by solder joints, which also provide mechanical and electrical contact between components and the printed circuit board. ACEA et al.[81] explains that technologically, pin compliant connectors avoid the difficulties encountered in soldering a large number of closely spaced pins. The total thermal mass can be so large that it is difficult to achieve the correct temperature throughout the connector for the solder to flow and wet the surfaces. The situation is even more difficult with lead-free solders due to their slower wetting and higher assembly temperature. As solder is not used, smaller pads can be used around each pin, so that they can be placed closer together. The thermal situation will be even more critical because of the miniaturization of pins and components. Miniaturization, however, is needed because of performance and resource issues.

Furthermore, ACEA et al.[82] remarks, high-current applications, which have a lot of copper on the PCB and on the contact element, will have difficulties if soldering is to be attempted. The additional copper will increase the thermal mass of the PCB and make it even more difficult to reach the soldering temperature, which is required to produce a reliable solder joint. The result will be bad hole filling, and connectivity and wettability problems.

5.2.2 Substitution of Lead

5.2.2.1 Differences to RoHS

CoPiCS are used also in electrical and electronic equipment (EEE) which falls under the scope of Directive 2011/65/EU (RoHS 2). Exemptions 11(a) and 11(b) in Annex III of RoHS 2, allowing the use of lead in CoPiCS in EEE, expired in 2010 and in January 2013 respectively.

---

[78] Op. cit. ACEA et al. (2013b)

[79] Op. cit. ACEA et al. (2013b)

[80] Op. cit. ACEA et al. (2013b)

[81] Op. cit. ACEA et al. (2013b)

[82] Op. cit. ACEA et al. (2013b)

ACEA et al.[83] quotes the reports of Oeko-Institut[84] from the former reviews of the CoPiCS exemptions in the RoHS and ELV Directive in 2009 and 2010 to explain the differences between CoPiCS and their use in RoHS- and ELV-related applications:

> *"Compliant pin connectors in most "RoHS" equipment, in particular on complex PCBs like in high end servers, are used among other reasons because pin connections can be repaired and replaced. For repair, rework and upgrade e.g. of servers, the compliant pin connectors must be removable and reinsertable without causing damages to the pins or the plated through holes, and still work reliable. Any bonding of the pins to the plated through hole (PTH) due to cold welding effects must be avoided in such uses under the scope of the RoHS Directive.*
>
> *This is a crucial difference between automotive and non-automotive press fit applications. While cold welding must be avoided in most RoHS equipment, it is the aspired effect in automotive press-fit applications. Cold welding of the pins to the PTH walls is necessary that the pin connector systems can reliably withstand the mechanical forces enacted onto them due to vibration and temperature changes, and the combination thereof. Pin movement in the holes would result in unreliable functionality. To achieve the cold welding effect, a higher pressure of the pin to the PTH wall is required. This higher pressure entails a higher force to insert the pins into the holes. ACEA et al.[85] claim that for pin connectors in telecom equipment typical insertion forces are 20 to 50 N/pin, while automotive pin connectors are inserted with forces up to 150 N/pin."*
>
> Source: Oeko-Institut[86] referenced in ACEA et al.[87].

5.2.2.2 Growth of Whiskers

ACEA et al.[88] states that whisker problems appear if lead-free chemical tin finishes on the PCB and galvanized tin surfaces on the press-fit pins are combined together (see examples in Figure 5-2).

---

[83] Op. cit. ACEA et al. (2013b)

[84] Op. cit. Oeko-Institut (2009,2010)

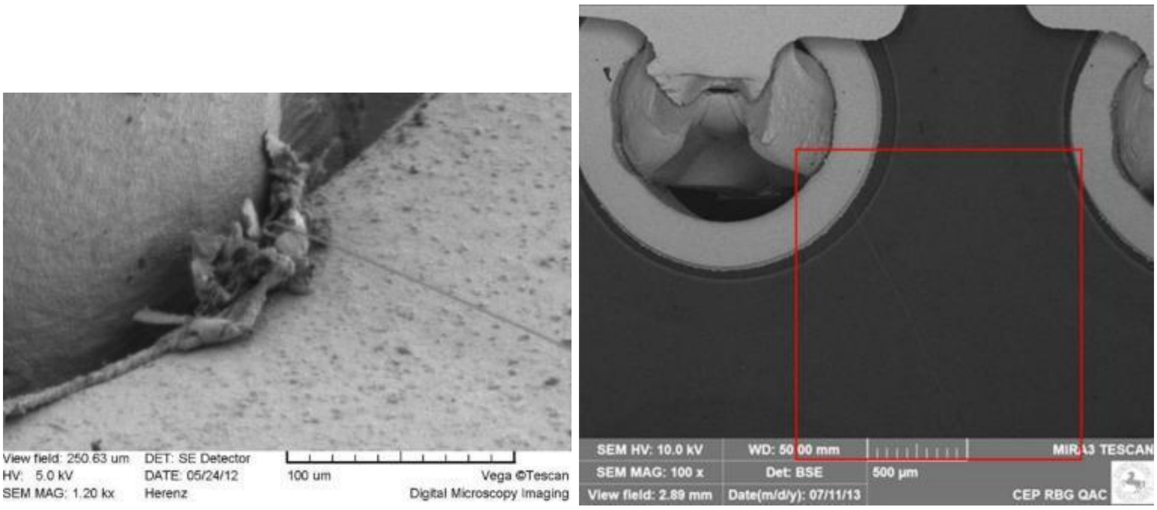
[85] Op. cit. ACEA et al. (2013b)

[86] Op. cit. Oeko-Institut (2009,2010)

[87] Op. cit. ACEA et al. (2013b)

[88] Op. cit. ACEA et al. (2013b)

Figure 5-2: Whiskers Examples (see within the “line” in the right part of the left picture, and in the red rectangle on the right picture):



Source: ACEA et al.[89]

ACEA et al.[90] states that large deformations in the entrance area of the press-fit zone and tin abrasions from the pin surface adhering to the PCB-bushing surface increase the probability of whisker growth.

ACEA et al.[91] explains that CoPiCS are currently in use with both Sn and SnPb surface finishes. Since the last review in 2009 several cases of multiple customer returns of electronic devices caused by extensive whisker growth occurred when pure tin finishes had been used for pilot applications.

ACEA et al.[92] highlights from literature that stress gradients within the Sn surface is one of the driving forces for Sn whiskers. In all cases the insertion forces have been medium to high as described earlier. Due to the required reliability of automotive applications high retention forces are needed. High retention forces calls for high insertion forces which automatically results in high strain levels in the contact zone. This is the reason why at the border of the contact area between press-fit pin and plated through hole (PTH), high stress gradients are present which tend to generate whisker growth with high probability of electrical short circuit. Even CoPiCS with high insertion forces, which haven’t been estimated as highly prone to whisker growth due to their still moderate deformation shape, showed whisker returns recently. This leads ACEA et al.[93] to the conclusion that the occurrence of press-fit whiskers is not yet fully

89 Op. cit. ACEA et al. (2013b)

90 Op. cit. ACEA et al. (2013b)

91 Op. cit. ACEA et al. (2013b)

92 Op. cit. ACEA et al. (2013b)

93 Op. cit. ACEA et al. (2013b)

understood. This especially holds for the immersion tin layer production and resulting surface structures as well as the galvanic tin plating chemistry behaviour and the interplay of these factors.

ACEA et al.[94] says that the lack of knowledge led in all cases to a re-introduction of SnPb platings with a Pb-content of 5-10%, which immediately solved the whisker issue. In detail the mechanism of Pb preventing SnPb from generating long whiskers is not understood so far. Therefore, it is not possible yet to develop a substitute of Pb on a knowledge base with sufficient whisker suppression. Consequently mass production with an adequate substitute for Pb is not possible at the moment.

ACEA et al.[95] formulates three main requirements for an adequate substitute for Pb:

- Find a substitute of Pb in order to reach high reliability;
- Development of the bath chemistry and bringing it to high volume series production level worldwide and from different suppliers; and
- Proof of sufficient whisker suppression over the whole range of parameter scattering in the galvanic of the press-fit contacts and manufacturing process of the ECU with all interdependencies.

5.2.2.3 Compliance Activities in the Past Years

ACEA et al.[96] states that over the past few years an industry working group investigated the use of lead free CoPICS. In this working group a number of OEMs (original equipment manufacturers), Tier1s and Tier2s are working together to make lead avoidable as soon as possible. Information on the following potential approaches was provided:

2) <u>Geometrical change</u>

ACEA et al.[97] says that Oeko-Institut[98] had recommended making the pins smaller and the holes bigger. The automotive industry needs a cold welding effect for its connections. Cold welding effect needs high pressure between the pin and the PCB. If the geometry of the pins is changed, these pressures will not be present between the pin and the PCB.

3) <u>Thickness of tin-lead plating</u>

According to ACEA et al.[99], the thickness of the surface layers has been reduced in order to minimize the amount of lead in the compliant pin connector systems.

---

[94] Op. cit. ACEA et al. (2013b)

[95] Op. cit. ACEA et al. (2013b)

[96] Op. cit. ACEA et al. (2013b)

[97] Op. cit. ACEA et al. (2013b)

[98] Op. cit. Oeko-Institut (2010)

[99] Op. cit. ACEA et al. (2013b)

4) <u>Protection with lacquer layer</u>

ACEA et al.[100] states that a lacquer layer can't stop whisker growth. Tests showed that lacquer also lead to contact problems. Furthermore, the use of lacquer would result in additional resources and a big environmental impact.

5) <u>Gold surfaces</u>

ACEA et al.[101] states that Oeko-Institut[102] had recommended investigating gold surfaces. In the 2009 [RoHS] review, gold surfaces were rejected due to their insufficient cold welding properties. Despite the stakeholders in the RoHS Annex review having rejected gold surfaces, the automotive industry nevertheless investigated gold-combinations. These combinations showed minor reliability results in test series, increasing resistance after temperature changes and less retention forces after vibration due to loss of cold welding effects. The gold connections could be described as brittle, intermetallic connections.

6) <u>Alternative surface materials of pins and PCBs</u>

ACEA et al.[103] reports that on a generic level, there has been evaluation and investigation of alternative surfaces that might replace SnPb as well as Sn. Especially treated indium surfaces and certain SnAg compound surfaces might be candidates to partially replace surfaces used today. Both, SnAg and In (indium)-bath chemistries were developed together with a specialized galvanic plating supplier for each plating in 2009-2011 with great efforts and costs on both sides, suppliers and Tier1s.

According to ACEA et al.[104], a test program was set up in order to prove the long-term reliability by Design of Experiments, Process and Product-FMEA (Failure mode and effect analysis), process controls and whisker tests. Now, first experiences and results are available for SnAg in one pilot product field in series, since 2011 ongoing. For indium, first product validations are scheduled. Although the tests are running overall well, sometimes sudden unexpected peaks in the failure ratio appear. Further on, transfer to high volume production from galvanic side and experience with other automotive applications is missing. At last, this is a single source and just available in Germany. There is no solution worldwide available for SnAg and In galvanic.

Beside metallic surfaces, ACEA et al.[105] describes an extensive study investigating "press-fit at OSP (Organic Surface Protection)" as an alternative Sn-free PCB finish to avoid one possible source of whisker growth. The alternative PCB finish with

---

[100] Op. cit. ACEA et al. (2013b)

[101] Op. cit. ACEA et al. (2013b)

[102] Op. cit. Oeko-Institut (2010)

[103] Op. cit. ACEA et al. (2013b)

[104] Op. cit. ACEA et al. (2013b)

[105] Op. cit. ACEA et al. (2013b)

OSP in combination with Sn, SnAg, and In pin surfaces increase the number of alternative surface combinations. The evaluation of the results is not finished yet, but shows even higher insertion forces and PCB through hole deformation compared to immersion Sn PCBs. This indicates an increased risk for both manufacturability and reliability. Besides, the combination OSP on PCB and Sn on the pin still shows too high whisker growth.

ACEA et al.[106] sums up the assessment of working group "Press fit in OSP PCB" as follows:

- Press fit with OSP shows potential in future;
- Lower performance in comparison to state of the art;
- Shown weaknesses have to be ensured by:
  - Further investigations on PCBs and Pins;
  - Pilot projects between OEMs, Tier1s and Tier2s at both the component and vehicle levels.

5.2.3 Road Map for Substitution or Elimination

ACEA et al.[107] states that the industry consortium will perform further research in the next years. The pilot projects should mainly focus on Organic Surface Protection, change of basic printed circuit board materials and lead-free pins. Unfortunately, until now a lot of uncertainty and unknown topics occur during the development of surfaces of CoPiCS. The process is more research than development. So it is not ensured that the milestones can be reached.

ACEA et al.[108] lists the main development tasks:

<u>Task 1: Finish investigation</u>

A replacement of the wide range of SnPb applications cannot be reached in a short range time line. Generic investigations, e.g. at elevated temperatures, in miniaturized and high current applications are not finished or even started yet (time frame - 3 years).

<u>Task 2: Design and product validation</u>

Design and product validations need to be planned and performed and finally introduced on pilot projects to the field (time frame - 3 years).

<u>Task 3: Long-term reliability tests</u>

---

[106] Op. cit. ACEA et al. (2013b)

[107] Op. cit. ACEA et al. (2013b)

[108] Op. cit. ACEA et al. (2013b)

It will take several years to gain enough field experience and roll-out the alternative plating to the diversity of applications in all presently known and future environments in light vehicles (time frame - 5 years).

<u>Task 4: Ramp-up production of lead-free CoPiCS</u>

In parallel, the production of the alternative plating must be ensured on a worldwide basis.

ACEA et al.[109] reports that one prototype line exists for each of the two mentioned alternative plating finishes, even though only for a relatively low amount of pins. The galvanic set-up needs to be transferred to the different economic regions (time frame - 3 years). A reasonable supplier portfolio needs to be built-up (time frame - 5 years).

Because of the uncertainty, ACEA et al.[110] requests the extension of Exemption 8(f) with a review date.

5.2.4 TE Connectivity's Arguments Against the Continuation of the Exemption

TE[111,112] claimed that there is no technical reason why Exemption 8(f) should be continued. TE[113] substantiates this statement saying that some action pin, multispring press in zones, in several versions, customized and as catalogue versions, are available. They are used for single pin insertion, assembled in connectors, as well as placed in overmoulded housings with more than several hundred part numbers. The hole diameters are 0.9, 1.0 and 1.5 mm.

5.2.4.1 Use of lead-free CoPiCS in Automotive Applications

In TE[114], TE Connectivity considers itself as market leader and has executed, with the release of the ELV Directive in 2003, a general change from tin-lead finishes to lead free finishes. All electroplating applications for use in automotive applications since 2003 conform with the ELV requirements (content of Pb in layer <0.1%), produced with lead free qualified electroplating baths.

TE[115] states that since 2003 over 10 billion compliant pins with ActionPin press-in zones in automotive airbag control units have been supplied. One example for the use of lead-free CoPiCS is an airbag ECU with millions of devices (every third car) delivered to the automotive market. There are much more applications with compliant

---

[109] Op. cit. ACEA et al. (2013b)

[110] Op. cit. ACEA et al. (2013b)

[111] TE (2013a) TE Connectivity document "TE Connectivity 2013a.pdf", sent via e-mail by Mr. Waldemar Stabroth to Mrs. Yifaat Baron, Oeko-Institut, on 30.10.2013

[112] TE Connectivity are a designer and manufacturer of connection and communication components.

[113] TE (2014a) TE Connectivity document "Questionnaire-1_TE_Exe-8f.pdf", sent via e-mail by Mr. Waldemar Stabroth to Mrs. Yifaat Baron, Oeko-Institut, on 17.01.2014

[114] Ibid.

[115] Ibid.

pins in the field, e.g. Multispring in ABS control units and other applications without any Pb content.

5.2.4.2 Prevention of Cold Welding During Insertion

TE[116] describes that, in order to prevent cold welding in the insertion process, during the insertion process the frictional behaviour of the press in system (pin and hole) should be optimized. This can be done by using well shaped round and smooth surfaces (optimizing of stamping process), a lubricant or a material combination, which is optimized to the used PCB technology. When using Sn as a surface layer the Sn thickness has to be optimized to the PCB. To prevent slivers and material wear, the tin thickness should be minimized to a stable press in process.

According to TE[117], the given minimum thickness depends on the press in zone type and the PCB hole/technology. When the Sn layer is too thin, stick slipping and cold welding effects cause a higher press in force and can have a negative impact on the quality. In worst cases the hole can be damaged. Cold welding after pressing in is a sign of a perfect electrical and mechanical connection and therefore an intended quality sign.

5.2.4.3 Prevention of Whisker Growth

TE[118] explains that Sn whisker growth requires as a precondition the presence of Sn and a mechanical stress gradient, which is applied onto the Sn. The more pure tin is present, the more and longer the whiskers are. SnPb is also a cause of whiskers, but reduced in amount and length, compared to pure Sn. To reduce the whisker growth in pure tin compliant pin applications, TE[119] reduces the amount of Sn (fodder for whiskers) to a minimum layer thickness (Sn flash) and shapes the compliant pin zone as smooth as possible during the manufacturing process.

5.3 Critical Review

5.3.1 Restriction of the Scope of Exemption 8(f)

ACEA et al. were asked to comment on TE's statements that lead-free CoPiCS are reliable and available for all applications. ACEA et al.[120] showed that lead-free CoPiCS using the TE lead-free technology were tested, but exceeded the applicable failure thresholds.

---

[116] Ibid.

[117] Ibid.

[118] Ibid.

[119] Ibid.

[120] ACEA et al. (2014b) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA KAMA Answers_Questionnaire-2_Exe-8f_20140221.pdf", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 21.02.2014

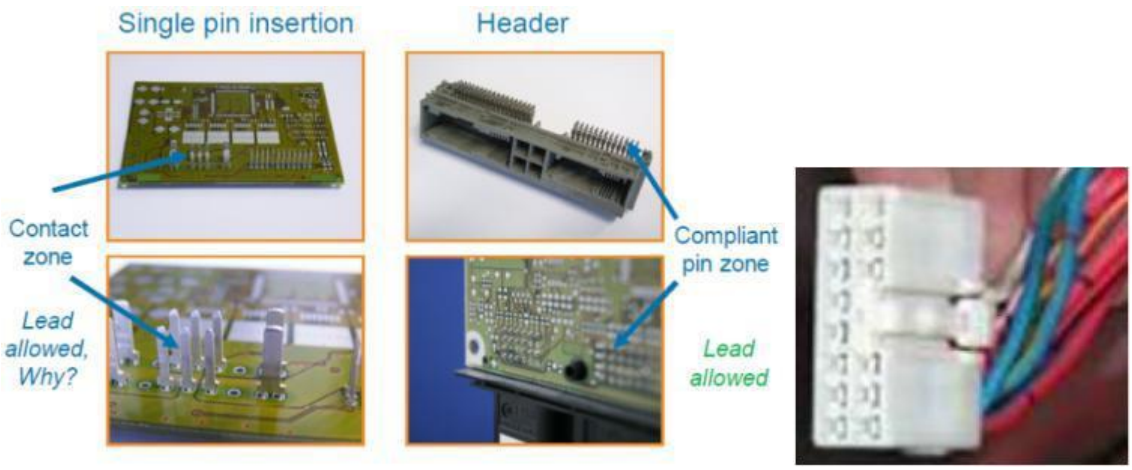
At the meeting on 9 May 2014 at Fraunhofer IZM in Berlin, it was agreed that ACEA et al. agree on a new wording of Exemption 8(f) that would reflect the current status of lead-free solutions for CoPiCS on the one hand, and on the other hand accommodate the still required use of lead. ACEA et al. and TE jointly worked out the below wording proposal for the future Exemption 8(f):

> *Lead in compliant pin connector systems other than the mating area of vehicle harness connectors*

ACEA et al.[121] explains that, based on the research of TE, the risk for whisker growth seems to be low on the mating area of a vehicle harness connector.

ACEA et al.[122] explains that mainly the CoPiCS in the below figures are used for electronic applications and call them “standard CoPiCS”. Standard CoPiCS are “vehicle harness connectors” as they always provide a 2-point connection where one side is the contact side/mating area connected via a harness to the customer applications and the second side is the connection to the printed circuit board by press fit technology. Figure 5-3 shows typical harness connectors.

Figure 5-3: Main Uses as Single Pin Insertion and Combination with a Header of Harness Connectors (left), and a Typical Harness Connector (right)



Source: TE Connectivity in ACEA et al.[123] (left), ACEA et al.[124] (right)

[121] ACEA et al. (2014f) ACEA, CLEPA, JAMA, KAMA stakeholder document “General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf”, sent via e-mail to Yifaat Baron,Oeko-Institut, by Peter Kunze, ACEA, on 28.05.2014

[122] ACEA et al. (2014g) ACEA, CLEPA, JAMA, KAMA stakeholder document “ACEA-et-al._Final-Questions_Exe-8f_20140703.pdf”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 04.07.2014

[123] Ibid.

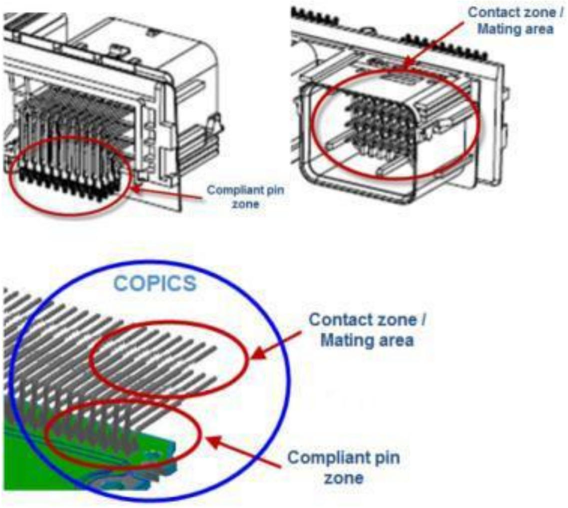
[124] Ibid.

ACEA et al.[125] differentiates between harness connectors (standard CoPiCS) and complex stamp grids. Unlike harness connectors, complex stamp grids, besides compliant pin zones, use other assembly and interconnection technologies like welding, “Schneid-Klemm,” etc. on the same stamp grid.

Typically, these stamp grids have no simple point-to-point connection but more the function of a printed circuit board combined with a complex three-dimensional form. For these kinds of complex parts, the surface needs to suffice the highest technical requirements of the interconnection technology. The application of different surfaces, for example lead and lead-free ones, is technically not feasible because of the complexity of the 3D-form. Therefore, if they use compliant pin zones, leaded tin could be used on the stamping grid.

ACEA et al.[126] defines the “mating area” as the “customer” side of the standard CoPiCS. The connection is here typically done with a harness connector. Figure 5-4 illustrates the situation.

Figure 5-4: Compliant Pin Zone and Contact Zone/Mating Area



Source: TE Connectivity in ACEA et al[127]

According to ACEA et al.[128], the definition “Lead in compliant pin connector systems other than the mating area of a vehicle harness connector” will reduce the use of lead for most of the CoPiCS, but keep the door open for the use of lead on complex stamp grids where it is still required.

125 Ibid.

126 Ibid.

127 Ibid.

128 Ibid.

According to ACEA et al.[129], the wording proposal of ACEA et al.[130] and TE Connectivity would result in the following situation concerning the use of lead:

- Contact zone/mating zone:
  - Customer side;
  - Contact with a harness connector;
  - Lead free.
- Compliant pin zone:
  - Printed circuit board side;
  - Lead-containing surface permitted.

ACEA et al.[131] explains that the circumference of the contact zone and the compliant pin zone is not clearly defined. The area in between these zones is therefore dependent on the technical requirements of the plating line. Typically, the lead surface in the compliant pin zone will be kept as small as possible.

5.3.2 Conclusions

TE and ACEA et al. during the consultation had disagreed on the status of lead-free solutions for CoPiCS. The opponents finally agreed and proposed a new wording excluding the use of lead where lead-free solutions are available, and restricting it to those applications, where its use is still unavoidable. Art. 4(2)(b)(ii) would therefore justify the continuation of the exemption with the new wording

> *Lead in compliant pin connector systems other than the mating area of vehicle harness connectors*

The above new wording restricts the scope of the exemption. In the above wording, the current exemption would be replaced by the revised one at the date of publication in the Official Journal of the European Union without a transition period. Adding to that, it would also apply to those vehicles that are already type approved and in series production. This would require redesigning and requalifying all currently used CoPiCS, which would exceed industry's labour capacity and would interrupt vehicle production for the EU market.[132]

By mistake, the transition period and the reference to the type approval were neglected in the previous report (dated 14/01/2015) and therefore have to be added to give industry a transition period to respond to the restricted exemption scope. A

---

[129] Ibid.

[130] Ibid.

[131] Ibid.

[132] Op. cit. Oeko-Institut (2010), p. 71 sqq.

new wording was therefore proposed and agreed with the stakeholders ACEA et al.[133] and TE Connectivity[134]:

i) *Lead in compliant pin connector systems for vehicles type-approved before 1 January 2017 and spare parts for these vehicles*

ii) *Lead in compliant pin connector systems other than the mating area of vehicle harness connectors for vehicles type-approved after 31 December 2016*

In the reviewers' opinion, the restriction of the revised exemption to new type approved vehicles as well as the transition period until end of December 2016 are appropriate. The transition period leaves sufficient time and is required to take into account the new situation in the development of vehicles that shall be type approved after December 2016.

5.4 Recommendation

Based on the available information, the consultants recommend the rewording of Exemption 8(f) to exclude the use of lead in compliant pin connector systems where lead-free solutions are available, and to restrict it to those areas where the use of lead is still unavoidable so that Art. 4(2)(b)(ii) justifies the continuation of the exemption.

In agreement with all involved stakeholders, the consultants recommend the following new wording of Exemption 8(f):

Materials and components	Scope and expiry date of the exemption
i) *Lead in compliant pin connector systems*	*For vehicles type-approved before 1 January 2017 and spare parts for these vehicles*
ii) *Lead in compliant pin connector systems other than the mating area of vehicle harness connectors*	*For vehicles type-approved after 31 December 2016* *Review in 2019*

To further adapt the exemption to the scientific and technical progress, it is recommended to review the exemption in 2019.

[133] ACEA et al. 2015: ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA and KAMA Type Approval.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Stefan Dully, ACEA, on 28.06.2015

[134] TE 2015: TE Connectivity document "TE Agreement to Revised Wording 8f.pdf", sent via e-mail by Mr. Waldemar Stabroth to Otmar Deubzer, Fraunhofer IZM, on 01.07.2015

5.5 References Exemption 8(f)

ACEA et al. 2013a ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013

ACEA et al. 2013b ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8f_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_f_/acea_clepa_jama_kama_contribution_Ex_8f_20131104.pdf; last accessed 27.12.2013

ACEA et al. 2014a ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8f_20131104.pdf", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 21.02.2014

ACEA et al. 2014b ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA KAMA Answers_Questionnaire-2_Exe-8f_20140221.pdf", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 21.02.2014

ACEA et al. 2014c ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA and KAMA Answers_Questionnaire-3_Exe-8f_20140404.pdf", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 04.04.2014

ACEA et al. 2014d ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA and KAMA Answers_Questionnaire-4_Exe-8f_20140507.pdf", received by Otmar Deubzer, Fraunhofer IZM, via e-mail from Peter Kunze, ACEA, on 08.05.2014

ACEA et al. 2014e ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA Lighthouse Applications.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 15.05.2014

ACEA et al. 2014f ACEA, CLEPA, JAMA, KAMA stakeholder document "General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf", sent via e-mail to Yifaat Baron,Oeko-Institut, by Peter Kunze, ACEA, on 28.05.2014

ACEA et al. 2014g ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA-et-al._Final-Questions_Exe-8f_20140703.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 04.07.2014

ACEA et al. 2015	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA and KAMA Type Approval.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Stefan Dully, ACEA, on 28.06.2015
ELV Directive	Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20130611:EN:PDF; last accessed 05.12.2013
Oeko-Institut 2009	Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e. V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, retrievable from http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20 November 2011
Oeko-Institut 2010	Zangl, S.; Hendel, M.; Blepp, M.; Liu, R.; Gensch, C. (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, retrievable from https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 05.09.2013
TE 2013a	TE Connectivity document "TE Connectivity 2013a.pdf", sent via e-mail by Mr. Waldemar Stabroth to Mrs. Yifaat Baron, Oeko-Institut, on 30.10.2013
TE 2014a	TE Connectivity document "Questionnaire-1_TE_Exe-8f.pdf", sent via e-mail by Mr. Waldemar Stabroth to Mrs. Yifaat Baron, Oeko-Institut, on 17.01.2014
TE 2014b	TE Connectivity document "E-Mail TE Pb on Pin Only 2014-04-01.pdf", sent via e-mail by Mr. Waldemar Stabroth to Mrs. Yifaat Baron, Oeko-Institut, on 01.04.2014
TE 2015	TE Connectivity document "TE Agreement to Revised Wording 8f.pdf", sent via e-mail by Mr. Waldemar Stabroth to Otmar Deubzer, Fraunhofer IZM, on 01.07.2015

6.0 Exemption 8 (g) “Lead in solders of flip chip packages”

Abbreviations and Definitions

BGA	Ball grid array
CMOS	Complementary metaloxide semiconductor
FC	Flip chip
FCP	Flip chip package

Declaration

The phrasings and wordings of stakeholders’ explanations and arguments have been adopted from the documents provided by the stakeholders as far as possible. Formulations have been altered in cases where it was necessary to maintain the readability and comprehensibility of the text.

6.1 Description of Requested Exemption

ACEA et al.[135] applies for the continuation of Exemption 8(g) in Annex II of the ELV Directive without an expiry date. The current wording of this exemption is:

> *Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages.*
>
> *The exemption shall be reviewed in 2014.*

6.1.1 History of the Exemption

Goodman[136] first reviewed this application concerning a possible exemption from the RoHS Directive 2002/95/EC[137]. As a result, Exemption 15 was listed in the annex of

---

[135] ACEA et al. (2013b) ACEA, CLEPA, JAMA, KAMA stakeholder document “acea_clepa_jama_kama_contribution_Ex_8g_20131104.pdf”, submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_g_/acea_clepa_jama_kama_contribution_Ex_8g_20131104.pdf ; last accessed 20.11.2013

[136] Goodman (2004) Paul Goodman, Philip Strudwick, Robert Skipper: Technical adaptation under Directive 2002/95/EC (RoHS) - Investigation of exemptions – Final Report. ERA Report 2004-0603, December 2004, retrieved from http://ec.europa.eu/environment/waste/weee/pdf/era_technology_study_12_2004.pdf; last accessed 06.12.2013

[137] RoHS 1 (2002) Directive 2002/95/EC of the European Parliament and of the Council of 27.01.2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment,

RoHS 1, with an identical wording to that of the current ELV Exemption 8(g). The exemption was reviewed again in 2008[138] under the RoHS 1 regime. The Commission followed the consultants' recommendation[139] and granted the continuation of the exemption without specifying an explicit expiry date so that the exemption would have remained valid until 2014. The exemption was later transferred as Exemption 15, without change, to Annex III of the RoHS recast Directive 2011/65/EU[140]. Article 5(2)[141] of the RoHS Directive stipulates that all exemptions are to have a limited duration. If the maximum duration is to apply to Exemption 15 of RoHS, it shall remain available for most equipment until 22 July 2016 and for equipment of the RoHS Annex I category 8 (medical devices) and category 9 (monitoring and control equipment) for 7 years, starting when the category is to come into the scope of RoHS (i.e., from the 22 July 2014/2016/2017 until 22 July 2021/23/24).

In 2009, just after the review under RoHS 1, the application was also reviewed, concerning a possible exemption from Directive 2000/53/EC[142]. Based on the results of the previous review of Exemption 15 under the RoHS Directive, the consultants' recommended granting the exemption[143], and it was added as Exemption 8(g) to Annex II of the ELV Directive with the above wording and a review date in 2014.

---

retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; last accessed 05.12.2013

138 The consultation documents can be found here: http://rohs.exemptions.oeko.info/index.php?id=31

139 Oeko-Institut (2009) Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e.V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, retrievable from http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20.11.2011

140 RoHS 2 (2011) Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast), retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; last accessed 05.12.2013

141 Article 5(2) of the RoHS Directive stipulates: "Measures adopted in accordance with point (a) of paragraph 1 shall, for categories 1 to 7, 10 and 11 of Annex I, have a validity period of up to 5 years and, for categories 8 and 9 of Annex I, a validity period of up to 7 years... For the exemptions listed in Annex III as at 21 July 2011, the maximum validity period, which may be renewed, shall, for categories 1 to 7 and 10 of Annex I, be 5 years from 21 July 2011 and, for categories 8 and 9 of Annex I, 7 years from the relevant dates laid down in Article 4(3), unless a shorter period is specified." See also clarification in RoHS FAQ Document: http://ec.europa.eu/environment/waste/rohs_eee/pdf/faq.pdf.

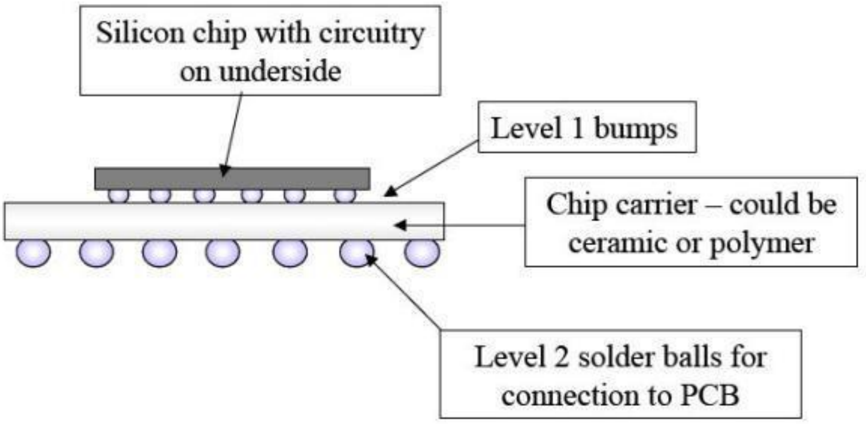
142 ELV Directive (2000) Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20130611:EN:PDF; last accessed 05.12.2013

143 Oeko-Institut (2010) Zangl, S.; Hendel, M.; Blepp, M.; Liu, R.; Gensch, C. (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, retrievable from

6.1.2 Technical Description of the Exemption

Figure 6-1 displays the schematic view of a flip chip package (FCP).

Figure 6-1: Schematic View of a Flip Chip Assembly



Source: Goodman[144] (modified)

ACEA et al.[145] describes the status of lead use in FCP referring to Oeko-Institut[146]:

- For the level 2 interconnects, lead-free solders can be used. For level 1 interconnects, different solders are applied:
  - High melting point solders with 85% and more of lead, e. g. 97%Pb3Sn, 90%Pb10%Sn;
  - Lead-free solders, such as SnAg, Sn3.5%Ag0.7%Cu (SAC);
  - Gold, copper or gold tin;
  - Eutectic solder (63%Sn37%Pb).
- The solders used on level 1 in the flip chip connections must be:
  - Resistant to electro-migration failure at the extremely high current densities required;
  - Able to create a solder hierarchy that allows staged assembly and rework of components in the manufacture process; and

---

https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 05.09.2013

144 Op. cit. Goodman (2004)

145 Op. cit. ACEA et al. (2013b)

146 Op. cit. Oeko-Institut (2009)

- Have high ductility to reduce thermo-mechanical stress in under bump metallurgy structures in particular in larger dies.

In 2008, lead-free solders could not yet provide all these functionalities to a sufficient degree and hence were not appropriate to replace the leaded solders. Lead solders in particular were important for high reliability applications, large dies, and high performance applications with high current densities.

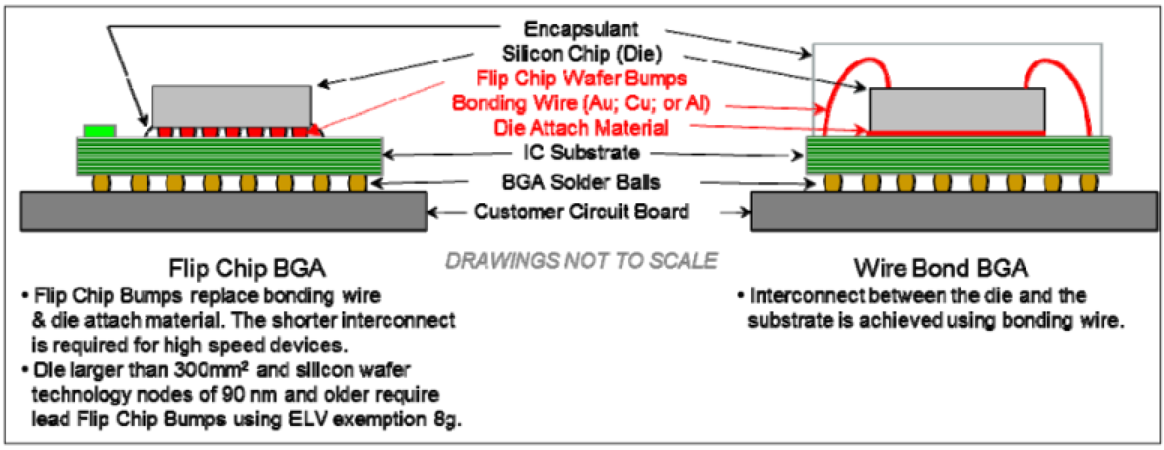
ACEA et al.[147] explains that flip chip interconnection technology is used in highly complex multi-chip and stacked package integrated circuits, e.g. controllers for communication equipment. The technology offers advantages in high frequency (HF) applications where heat dissipation and radiation (heat as well as electromagnetic) are critical. Controllers using these advantages can be found in a wide variety of uses in vehicles, e.g.

- Long range distance control;
- Lane departure warning systems;
- Frontal projection systems;
- Car radio;
- Vision systems;
- Car-infotainment;
- Traffic sign recognition;
- Navigation systems;
- Telematic systems;
- Head-up displays;

Figure 6-2 shows the typical design of flip chip devices in comparison to the traditional design using wire bond connections. The “Flip Chip Wafer Bumps” are produced with lead solder.

[147] Op. cit. ACEA et al. (2013b)

Figure 6-2: Design of Flip Chip Devices and Traditional Wire Bond Connected Packages



Source: ACEA et al.[148] / ACEA et al.[149]. BGA = Ball grid array

ACEA et al.[150] claims that as of today, a significant number of existing automotive flip chip applications cannot be converted into lead-free and the use of lead therefore remains unavoidable.

6.1.3 Amount of Lead Used under the Exemption

ACEA et al.[151] indicates that the typical lead content for a lead flip chip die within a semiconductor product may vary from a minimum of 0.5 mg to a maximum of 300 mg, depending primarily upon the size and number of bumps. The median estimated lead from flip chip bumps under ELV is 0.015 grams. The flip chip products are used in selected few sockets within automotive applications. There are no metrics to identify the number of lead flip chip components within an average vehicle.

ACEA et al.[152] calculates that, assuming one to three flip chip components per vehicle and based upon the latest estimated 13.4 million registered units in the European Economic Area (EU + Norway, Iceland and Liechtenstein), the total lead placed on the EU market is estimated with about 0.2 to 0.6 metric tonnes per year.

---

[148] Op. cit. ACEA et al. (2013b)

[149] ACEA et al. (2013c) ACEA, CLEPA, JAMA, KAMA stakeholder document “ACEA, CLEPA, JAMA, KAMA Answers_Questionnaire-1_Exe-8g_20131220.pdf”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 20.12.2013

[150] Op. cit. ACEA et al. (2013b)

[151] Op. cit. ACEA et al. (2013b)

[152] Op. cit. ACEA et al. (2013b)

6.2 Stakeholders' Justification for Exemption

ACEA et al.[153] provides the following reasons for the continued use of lead in the requested exemption:

- Chip sizes of more than 300 mm^2, or fabrication processes using structures of 90 nm and above or/and additional solder die attach;
- The incremental stress from the Cu pillars or from other lead-free materials introduces severe long term reliability problems such as bump integrity, dielectric cracking and die cracking;
- The influence of cooling parameters having more influence on microstructure[154];
- The thermo mechanical load during the processing of the FCPs limits the achievable and required long term reliability;
- In vehicle use, the component has to tolerate high mechanical and thermal stress over a long period of time

According to ACEA et al.[155] , the chip and factory design as well as the process technology are often incompatible with the stiff Pb-free flip chip bumps for designs based upon older CMOS (complementary metal-oxide semiconductor) technology with 90 nm or larger printed transistor line width. The conversion to Pb-free bumps results in reliability failures.

Similarly, ACEA et al.[156] states that products in semiconductor manufacturing technologies with a die size greater than 300 mm^2 do not meet automotive long-term reliability requirements. The large dies are especially susceptible to bump failures near the corners when using stiff or less pliable Pb-free bumps.

ACEA et al.[157] admits that newly developed lead free flip chip products are available for die sizes of less than 300 mm^2 and less than 90 nm node structures, but by far not yet covering all the various products, designs and applications in the current uses described above (see applications detailed in Section 6.1.2). For these products, long-term reliability and performance under harsh environment, still has to be assessed and field experience gained. These lead free flip-chip applications typically fail the essential AEC-Q 100[158] specification for the endurance demands, thus excluding their usage for automotive applications.

---

[153] Op. cit. ACEA et al. (2013b)

[154] S. Wiesse: Verformung und Schädigung von Werkstoffen der Aufbau- und Verbindungstechnik e.g. p 455 ff; Springer Verlag, Heidelberg 2010 ff; source as referenced in ACEA et al. (2013b)

[155] Op. cit. ACEA et al. (2013b)

[156] Op. cit. ACEA et al. (2013b)

[157] Op. cit. ACEA et al. (2013b)

[158] http://www.aecouncil.com/AECDocuments.html; source as referenced in ACEA et al. (2013b)

ACEA et al.[159] states that significant progress has been made in alternative interconnection and packaging technologies. However, challenges remain with regard to the use of substitute materials and interconnection technologies. Newly designed products using that substitute may not be suitable for existing and forthcoming applications in vehicles, especially, when considering new technology fields like (hybrid) electric vehicles and the requirements on components resulting thereof. These developments are currently ongoing, but still will need much effort within the automotive industry and related supply chain for successful completion.

ACEA et al.[160] explains that automotive flip chip technology is relatively new. Applications such as engine control or advanced traffic control and passenger safety systems (e.g. “eCall”) require advanced solutions, where lead free flip chip may not be possible. The semiconductor industry has been converting new products to lead-free flip chip bumps and has launched extensive design and development activities to find lead free alternatives for the automotive industry. These lead-free technologies have been introduced for product designs using structures less than 90 nm in width and with an area less than 300 mm^2. New materials for lead-free flip chip connections have been developed and implemented, such as copper pillars. The wafer fabrication technologies for less than 90 nm were designed for lead-free bumps. With the shrinking fabrication geometries, the dies become smaller and create less stress on the bonding pads and circuitry, as temperatures change and packages flex. Also, the new technologies were designed with a more robust wafer stack in the fabrication process, able to withstand the additional stress. As a result, many flip chip devices contain lead-free bumps for connecting the die to the integrated semiconductor package but, as stated above, these are not yet available and/or qualified for automotive applications.

According to ACEA et al.[161], manufacturers have unsuccessfully attempted to retrofit lead-free bumps onto older and larger technology products designed for lead bumps. When attempted, the increased stress from the rigid lead-free bump resulted in product reliability failures. Due to quality and reliability concerns, some contract assembly sites do not offer lead-free flip chip bumps for the older and larger die, so there may be no alternatives available for these products.

According to ACEA et al.[162], the semiconductor industry is known for rapid product innovation. Products in vehicles have, however, a long life cycle. Flip chip connections are used on high power, high reliability and high performance products. In these applications, the OEM market demands full characterization of all possible chip defects. This historical information is only available through years of evaluation. Product delivery for product replacement and repair and for other highly custom and low volume applications may continue for decades after a product passes its peak

---

[159] Op. cit. ACEA et al. (2013b)

[160] Op. cit. ACEA et al. (2013b)

[161] Op. cit. ACEA et al. (2013b)

[162] Op. cit. ACEA et al. (2013b)

sales volume. Companies may ship inventory that was fabricated years ago for these low volume products. This further complicates attempts to redesign with lead-free materials during the tail-end of a [FCP] product life cycle.

ACEA et al.[163] states that it is essential that Exemption 8(g) is extended because:

- Concerned applications for these products include safety critical applications like "emergency call", "car to car communication" and applications in regulated areas like "telematics";
- The development and transition cycles in the global automotive industry can extend beyond a decade; and
- Flip chip technology supports the ongoing miniaturization of components and contributes to resource efficiency.

6.2.1 Road Map for Substitution or Elimination

ACEA et al. were asked to provide a roadmap for the substitution or elimination of lead. ACEA et al.[164] explains that for selected high power, high reliability and/or high performance products, the ELV Exemption 8(g) will be required during the development and evaluation of substitute materials and interconnection technologies. Specifically, ACEA et al.[165] considers that Exemption 8(g) is necessary for a time period related to the following concerns:

- Until replacement materials and processes are successfully identified for large die, high power and high reliability products;
- Until long term reliability is assessed and qualified under the harsh use conditions in vehicles according to automotive specifications (e.g. AEC-Q100); and
- Until products become available for automotive applications from a reasonable number of suppliers and in sufficient quantity.

ACEA et al.[166] claims that after an automotive suitable lead free material is identified, and material / process development is frozen, usually a minimum of 6 years will be required to qualify the new material through the whole supply chain. Based upon the current status of these special products, it is not possible to estimate a transition date. Product delivery for replacement and repair will need to continue for the life of type approved vehicles.

---

[163] Op. cit. ACEA et al. (2013b)

[164] Op. cit. ACEA et al. (2013b)

[165] Op. cit. ACEA et al. (2013b)

[166] Op. cit. ACEA et al. (2013b)

6.3 Critical Review

6.3.1 Elimination of Lead

ACEA et al.[167] presents traditional wire-bonded BGA in the context of FCP in Figure 6-2. ACEA et al. and were therefore asked whether and how far wire bonded BGAs could replace FCP, thus eliminating the use of lead. ACEA et al.[168] explains the significant technical advantages of the flip chip technology[169]:

- High density packaging of complex integrated circuits, especially for high frequency applications like communication circuits cannot be realized by wire bond packages;
- Bond connections can only be made on the peripheral area of a chip. This causes strong limitations to the design of the chip (all input and output lines need to be placed to the outer area, thus the number of available input/output parts is limited;
- In FCP, input and output lines can be connected to all parts of the chip, and a much higher number of connecting points is possible. This offers the following advantages:
    - Better electrical properties to achieve good high frequency robustness;
    - Reduced height of assemblies;
    - Less space needed.

Besides the technical advantages, ACEA et al.[170] remarks that wire bonded BGA also contains lead in the die attach material displayed in Figure 6-2.[171]

Given the technical advantages of FCP, it is plausible that wire bonded BGA are not appropriate to eliminate the use of lead, all the more as wire bonded BGA also depend on the use of lead.

6.3.2 Substitution of Lead

According to ACEA et al.[172], lead free flip chip products are available for die sizes of less than 300 mm^2 and less than 90 nm node structures, but long-term reliability and performance under harsh environments and within field experience are still missing.

---

167 Op. cit. ACEA et al. (2013b)

168 Op. cit. ACEA et al. (2013c)

169 Steffen Wiese: Verformung und Schädigung von Werkstoffen der Aufbau- und Verbindungstechnik e.g. p 36f; Springer Verlag Heidelberg 2010; source as referenced in ACEA et al. (2013c)

170 Op. cit. ACEA et al. (2013c)

171 For details see review of Exemption 8(e)

172 Op. cit. ACEA et al. (2013b)

These lead free flip-chip applications typically fail the essential AEC-Q 100[173] specification for the endurance demands thus excluding their usage for automotive applications.

This raises the question what "typically" means in this context, as it may imply that some of these lead-free packages pass the AEC-Q 100 test. ACEA et al.[174] states that "typically" here means that these lead free technology products are not yet offered on the market with AEC-Q100 qualification, and that therefore the Automotive Industry assumes that such products are not yet mature enough to be offered to the Automotive Industry. The first step for use in automotive applications is that the FCP pass this specification. Then further reliability tests with prototype boards in laboratory and after that, tests in vehicles are necessary.

According to ACEA et al.[175], new high performance electronics technologies depend on the use of advanced FCP. ACEA et al. were asked how such modern technologies can be used in vehicles if they need to be evaluated for years before they are allowed in vehicles, and if no such components are qualified for automotive uses, as ACEA et al. claim.

ACEA et al.[176] explained that the FCP, which are in current use in automotive applications, were designed years ago, when the technology was developed and introduced after reliability was proven in the market. The lead free products are not compatible with these previous products. Previous products cannot be produced in the new technology (<90 nm node structure wafer technology). The functionality is not identical. Introduction of new lead free FCP will become possible, when the new technology flip chip products are available on the market, suitable and qualified for the automotive applications.

ACEA et al.[177] further claims that manufacturers have unsuccessfully attempted to retrofit lead-free bumps onto older technology products designed for lead bumps. The increased stress from the rigid lead-free bumps resulted in product failures. Due to quality and reliability concerns, some contract assembly sites do not offer lead-free flip chip bumps for the older die, so there may be no alternative for these products. The main issue is the cyclic thermo-mechanical load on and within the joints of bumps /die attach.

6.3.3 Conclusions

On the one hand, ACEA et al. had claimed that the AEC-Q 100 test is the indispensable condition for the use of lead-free FCP in automotive applications, and

---

[173] http://www.aecouncil.com/AECDocuments.html; source as referenced in ACEA et al. (2013b)

[174] Op. cit. ACEA et al. (2013c)

[175] Op. cit. ACEA et al. (2013c)

[176] Op. cit. ACEA et al. (2013c)

[177] Op. cit. ACEA et al. (2013c)

that no lead-free FCP have passed this test. On the other hand, ACEA et al. could not confirm that lead-free FCP are not in use in some vehicles. ACEA et al. could not clarify this contradiction. After several unsuccessful rounds of questionnaires, the open questions were discussed at the stakeholder meeting on 9 May 2014 at Fraunhofer IZM in Berlin.

ACEA et al.[178,179,180] and ACEA et al.[181,182,183] maintained their statement that no lead-free FCP have passed the AEC Q-100 test. At the meeting in Berlin, ACEA et al.[184] finally admitted that lead-free FCP that have passed the AEC Q-100 test are on the market.

ACEA et al. were asked to explain why, if lead-free FCP with automotive qualifications are available, they are not used in automotive applications, in particular for those applications, which are less challenging and less critical for security. ACEA et al.[185] explained that, depending on the application (e.g. car multimedia) and the place of installation within the car, vehicle manufacturers could require additional validation (compared to component manufacturer) and the use of lead-free FCP (or otherwise) is assessed on a case-by-case basis. This additional validation could exceed the standard validation e.g. AEC Q- 100 of the electronic component done by the component supplier and could lead to the possibility that a component has successfully passed the validation but still does not meet the requirements of the assembly or the vehicle. The qualification depends on several influencing factors. In case the "standard" qualification of the FCP is sufficient after verification within the application, lead-free FCPs are already used (e.g. for car multimedia) and will be used in future for suitable applications. However, ACEA et al. did not provide any further

---

178 ACEA et al. (2013a) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013

179 Op. cit. ACEA et al. (2013b)

180 Op. cit. ACEA et al. (2013c)

181 ACEA et al. (2014a) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA KAMA Answers_Questionnaire-2_Exe-8g_20140221", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 21.02.2014

182 ACEA et al. (2014b) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA and KAMA Answers_Questionnaire-3_Exe-8g_20140407.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 07.04.2014

183 ACEA et al. (2014c) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA and KAMA Answers_Questionnaire-4_Exe-8g_20140507.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 08.05.2014

184 ACEA et al. 2014b ACEA, CLEPA, JAMA, KAMA stakeholder document "General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf", sent via e-mail to Yifaat Baron,Oeko-Institut, by Peter Kunze, ACEA, on 28.05.2014

185 Ibid.

details. It is thus understood that lead-free FCP still have restrictions in automotive applications, but that they are probably used nevertheless.

ACEA et al. were further asked to provide information on how many and which types of lead-free FCP have passed the AEC Q-100 test. ACEA et al.[186] claims to have no such information available. ACEA et al.[187] did not explain why a worldwide consortium of vehicle manufacturers and their suppliers actually does not have any information on numbers and types or at least examples of lead-free FCP that are qualified according to the AEC Q-100 test. At the same time, ACEA et al. claim that this test is the obligatory initial qualification of components for automotive uses. The question arises how ACEA et al. undertake steps to avoid the use of lead in FCP where its use is avoidable according to Art. 4(2)(b)(II), if they do not even know which FCP have successfully passed this initial test qualifying them for further testing for automotive applications. At the same time, however, ACEA et al. ask for the continuation of the exemption. ACEA et al. were asked to clarify this situation.

ACEA et al.[188] reaffirmed that no further information is available concerning the lead-free FCP that have passed the initial qualification according to AEC Q100. They did not answer or comment on the question raised above.

Overall, the information provided is insufficient and does not give a clear picture of the actual situation of lead-free FCP technologies used in vehicles. The consultants are therefore not in a position to evaluate whether and where the use of lead in FCP is unavoidable in line with the requirements of Art. 4(2)(b)(II).

6.4 Recommendation

The information provided by ACEA et al. is insufficient and does not allow a proper assessment of the actual status of lead-free FCP in automotive uses. Since the applicant did not provide sufficient information justifying the continuation, it is recommended that the Commission cancel Exemption 8(g) or continue the exemption for now, scheduling a further review in 2016, if possible, building on the information gathered during the review of Exemption 15 in Annex III to the RoHS Directive which is currently scheduled to expire in July 2016.

---

186 Ibid.

187 Ibid.

188 ACEA et al. (2014e) ACEA, CLEPA, JAMA, KAMA stakeholder document “ACEA-et-al_Final-Questions_Exe-8g_20140703.pdf”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 4 July 2014

6.5 References Exemption 8(g)

ACEA et al. 2013a — ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013

ACEA et al. 2013b — ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8g_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_g_/acea_clepa_jama_kama_contribution_Ex_8g_20131104.pdf; last accessed 20.11.2013

ACEA et al. 2013c — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA, KAMA Answers_Questionnaire-1_Exe-8g_20131220.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 20.12.2013

ACEA et al. 2014a — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA CLEPA JAMA KAMA Answers_Questionnaire-2_Exe-8g_20140221", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 21.02.2014

ACEA et al. 2014b — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA and KAMA Answers_Questionnaire-3_Exe-8g_20140407.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 07.04.2014

ACEA et al. 2014c — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA and KAMA Answers_Questionnaire-4_Exe-8g_20140507.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 08.05.2014

ACEA et al. 2014d — ACEA, CLEPA, JAMA, KAMA stakeholder document "General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf", sent via e-mail to Yifaat Baron,Oeko-Institut, by Peter Kunze, ACEA, on 28.05.2014

ACEA et al. 2014e — ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA-et-al_Final-Questions_Exe-8g_20140703.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 04.07.2014

ELV Directive 2000 — Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, retrieved from http://eur-

	lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20130611:EN:PDF; last accessed 05.12.2013
Goodman 2004	Goodman, P.; Strudwick, P.; Skipper, R.; Technical adaptation under Directive 2002/95/EC (RoHS) - Investigation of exemptions – Final Report. ERA Report 2004-0603, December 2004, retrieved from http://ec.europa.eu/environment/waste/weee/pdf/era_technology_study_12_2004.pdf; last accessed 06.12.2013
Oeko-Institut 2009	Gensch, C.; Zangl, S.; Groß, R.; Weber, A. (Oeko-Institut e. V.); Deubzer, O. (Fraunhofer IZM); Adaptation to scientific and technical progress under Directive 2002/95/EC, Final Report, February 2009, p. 175, retrievable from http://ec.europa.eu/environment/waste/weee/pdf/final_reportl_rohs1_en.pdf; last accessed 20 November 2011
Oeko-Institut 2010	Zangl, S.; Hendel, M.; Blepp, M.; Liu, R.; Gensch, C. (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, p. 137, Freiburg, 28 July 2010, retrievable rom https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 5 September 2013
RoHS 1 2002	Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; last accessed 5 December 2013
RoHS 2 2011	Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast), retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32011L0065:EN:NOT; last accessed 5 December 2013

7.0 Exemption 8(h) Lead Solder to Attach Heat Spreaders to Heat Sinks in Power Semi-conductor Assemblies

ACEA et al.[189] support the continuation of Exemption 8(h) in Annex II of the ELV Directive until 2016. The current wording of this exemption is

> *"Lead in solder to attach heat spreaders to the heat sink in power semiconductor assemblies with a chip size of at least 1 cm^2 of projection area and a nominal current density of at least 1 A/mm^2 of silicon chip area;*
>
> *The exemption shall be reviewed in 2014"*[190]

Declaration

The phrasings and wordings of stakeholders' explanations and arguments were taken over from the documents provided by the applicant and other stakeholders as far as possible. They were altered in cases where it was necessary to maintain the readability and comprehensibility of the text.

7.1 Description of Requested Exemption

7.1.1 History of the Exemption

ACEA et al. had applied for this exemption in 2009, the proposed wording being "*Lead in solder for large power semiconductor assemblies*". Oeko-Institut[191] reviewed the

---

189 ACEA et al. (2013b) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_10d_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_10_d_/acea_clepa_jama_kama_contribution_Ex_10d_20131104.pdf; last accessed 11.11.2013

190 Directive 2000/53/EC (ELV) of the European Parliament and of the Council, Annex II, consolidated version from 11.06.2013

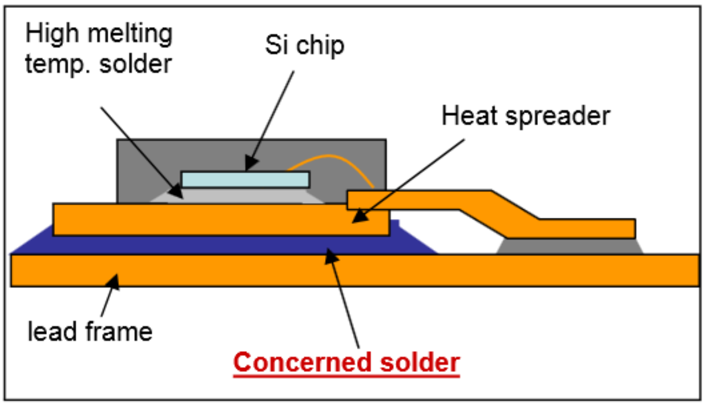
191 Oeko-Institut (2010); Zangl, S., Blepp, M., Deubzer, O., Gensch, C., Hendel, M., Liu, R., Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, Oeko-Institut e.V. in cooperation with Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM), retrievable from https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; accessed 05.09.2013

exemption request[192] and the Commission granted the exemption with the above wording and review date.

7.1.2 Technical Description of the Exemption

Figure 7-1 displays a power conductor assembly and the use of the lead solder exempted under Exemption 8(h). ACEA et al. explained in the 2009 review[193] that the lead-containing solder is used for the soldering of silicon chips (Si chips) of 1 cm^2 and more in surface area to lead frames. The "lead frame" serves as a heat sink in the assembly illustrated below (Figure 7-1).

Figure 7-1: Power Conductor Assembly with Exempted Use of Lead in Solder



Source: ACEA et al.[194]

It was further explained that applications relevant for this exemption regard any soldering of large size power semiconductor assemblies as used in inverters (= power control units to convert AC / DC and DC / AC)[195]. Insulated Gate Bipolar Transistors (IGBT) were referred to as an example, stating[196] that IGBT are silicone (Si) semiconductor chips comprising the main active component in power modules for Hybrid Electric Vehicles (HEV) and Electric Vehicles (EV). The semiconductor chips are converters that control the electric voltage and current between battery and the electric drive motor / alternator of a vehicle.

---

[192] For details see Oeko-Institut (2010), page 123 ff

[193] Op. cit. Oeko-Institut (2010)

[194] Op. cit. ACEA et al. (2013b)

[195] Quoted in Oeko-Institut (2010) as ACEA et al., Stakeholder Document "2009-05-20-Answers_Exemption_8a.doc", Additional Questions to Stakeholders Sent out May 13, Answers received via e-mail from Mr. Harald Schenk on 20.05.2009

[196] Quoted in Oeko-Institut (2010) as ACEA, JAMA, KAMA, CLEPA et al.; Stakeholder Document „ELV large_power semicons-final.PDF", submitted during online stakeholder consultation

ACEA et al.[197] explained that solder joints, attaching the heat spreaders to the heat sink in power semiconductor assemblies, have to fulfil the following requirements:

- The thermal conductivity of all components must be as high as possible and uniform over the complete chip surface, to ensure the fast flow of thermal energy from the chip to the lead frame;
- No appearance of cracks within the soldering phase; and
- The bond must be stable against cyclic loads.

Using lead-free solders, in 2009, these crucial properties could not be achieved for larger high power semiconductor assemblies with a chip size above 1 cm^2 of projection area and a nominal current density above 1 A/mm^2 of silicon chip area.

A detailed technical description of the exemption is available in the report of Oeko-Institut.[198].

7.2 Stakeholders Justification for Exemption

ACEA et al.[199] state that since developments for lead free connections are in the process of implementation, the existence of this specific exemption is not necessary for new type approved vehicles beyond the end of December 2015. These new lead-free soldering solutions are believed to have thermal and electrical properties comparable to those of lead solders for this application.

However, ACEA et al.[200] claim that the exemption needs to be maintained for vehicles type approved before January 2016, and for spare parts.

ACEA et al.[201] propose to keep the current exemption wording, but to add an expiry clause as follows:

> *"Vehicles type approved before 1 January 2016 and spare parts for these vehicles"*

7.2.1 Road Map for Substitution

The status and the remaining steps to be taken are explained in Section 7.3 below.

[197] See in Op. cit. Oeko-Institut (2010)

[198] Op. cit. Oeko-Institut (2010)

[199] Op. cit. ACEA et al. (2013b)

[200] Op. cit. ACEA et al. (2013b)

[201] Op. cit. ACEA et al. (2013b)

7.3 Critical Review

ACEA et al. state that lead-free solutions will be ready for use in new type approved vehicles after 2015. Thus, the use of lead will no longer be unavoidable, and an exemption according to Art. 4(2)(b)(II) of the ELV Directive will no longer be justified.

ACEA et al. were asked to illustrate in more detail the current status of lead-free soldering in the application covered by Exemption 8(h), and to explain the various steps remaining.

ACEA et al.[202] explain that the development of lead free soldering for large semi-conductors as covered by entry 8(h) has been advancing since 2007. A specific lead free soldering solution is sufficiently developed to have certainty about the feasibility of its implementation in production in the year 2015. The stages of development that are currently ongoing are:

- Studying of different combinations of chip (sizes) and materials (thicknesses);
- Studying of the in-duty temperature requirements of the bond, involving vehicle tests.

For the general overview of the project situation, ACEA et al.[203] provide the below figures extracted from a conference paper published in December 2012[204].

Figure 7-2 shows the generic problem with the current lead solder based solution and the process challenges related to void avoidance in the solder:

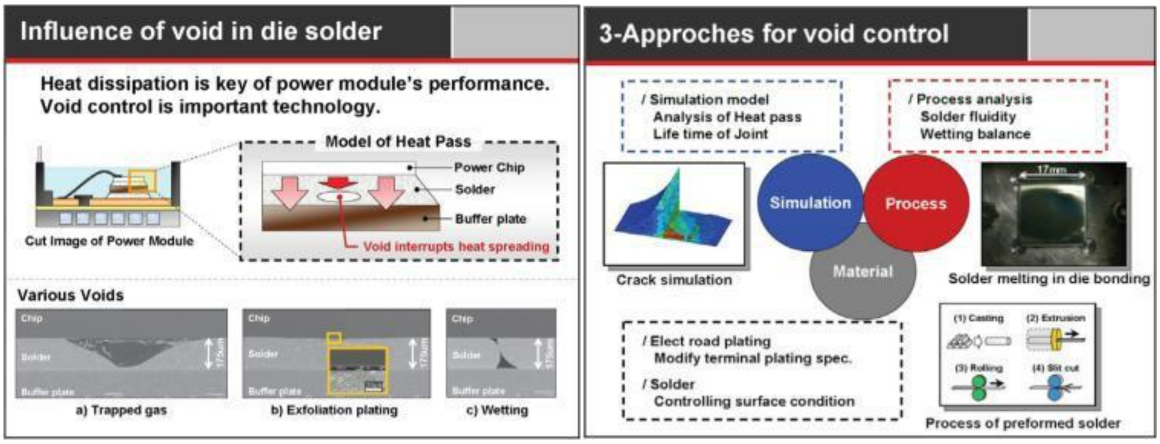
- Analysis of requirements;
- Experimentation with solder, process parameters, new processes.

[202] ACEA et al. (2013c) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA-et-al_Answers_Questionnaire-1_Exe-10d_20131206.pdf", received via e-mail by Otmar Deubzer, Fraunhofer IZM, from Peter Kunze, ACEA, on 06.12.2013

[203] Ibid.

[204] T. Serizawa: Joint Technology for assembly of chips and electrodes in high efficiency of mechatronics; SIA/CESA Congress 2012 Paris 2012 4/5 December; source as referenced in ACEA et al. (2013c)

Figure 7-2: Use of Application (schematic, left) and Development of Lead-free Solutions



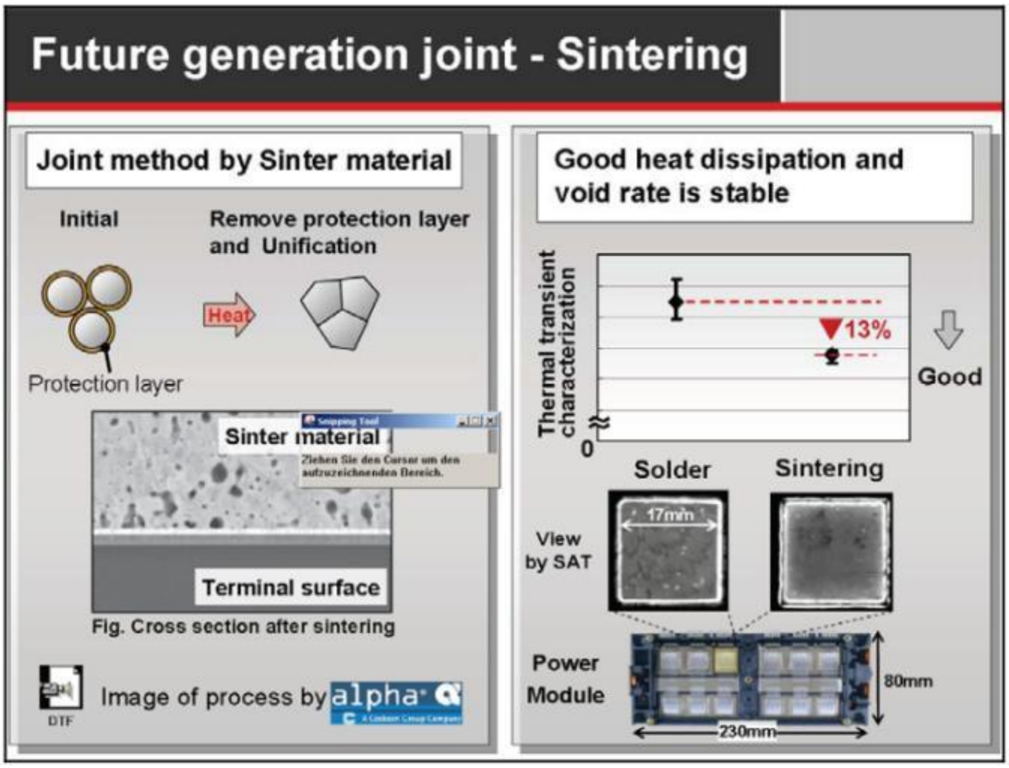
Source: ACEA et al.[205]

Furthermore, ACEA et al. explain that a further candidate to replace die bonding in the long run is sintering. Figure 7-3 illustrates this future longer-term solution envisaging the replacement of soldering with other joining processes introducing innovative materials. (ACEA et al.[206])

[205] Op. cit. ACEA et al. (2013c)

[206] Op. cit. ACEA et al. (2013c)

Figure 7-3: Developed and Applied Solution



Source: ACEA et al.[207]

ACEA et al.[208] highlight the importance of the above technology stating that the joint of large high-power semiconductors is at the focus of the vehicle manufacturers preparing for electric drive trains.

ACEA et al. ask for the continuation of the exemption until the end of 2015 in order to allow the final development and implementation of a lead-free solution replacing lead-solders in the application covered by Exemption 8(h). Furthermore, ACEA et al. request to continue the exemption after 2015 for vehicles type-approved before 2016.

In line with the practice of former exemption reviews[209], the technical qualification procedures for automotive applications like those under Exemption 8(h) justify the continued use of the exemption in vehicles type-approved before 2016. As power semiconductor assemblies form part of a complex system and only work properly if all parts of this system are aligned to each other, vehicles using lead-soldered power semiconductor assemblies should not be required to replace such assemblies with lead-free ones. Art. 4(2)(b)(II) allows the continued use of the exemption in spare

[207] Op. cit. ACEA et al. (2013c)

[208] Op. cit. ACEA et al. (2013c)

[209] See report Oeko-Institut (2010)[191]

parts for vehicles type-approved before 2016, as the use of lead in this cases is technically unavoidable.

7.4 Recommendation

Based on the available information and in the absence of contrary evidence, the consultants conclude that lead-free soldered solutions will be available for power semiconductor assemblies in the scope of Exemption 8(h) after 2015. The use of lead remains unavoidable until the end of 2015. The continuation of the exemption until the end of 2015 is therefore in line with the stipulations of Art. 4(2)(b)(II). The technical background of Exemption 8(h) justifies repealing the exemption for vehicles type-approved after 2016, allowing the continued use of the exemption in vehicles type-approved before that date and in spare parts for these vehicles.

The consultants propose the following wording and expiry date for the exemption:

Materials and components	Scope and expiry date of the exemption
Lead in solder to attach heat spreaders to the heat sink in power semiconductor assemblies with a chip size of at least 1 cm^2 of projection area and a nominal current density of at least 1 A/mm^2 of silicon chip area	*Vehicles type approved before 1 January 2016 and spare parts for these vehicles*

7.5 References Exemption 8(h)

ACEA et al. 2013a ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013

ACEA et al. 2013b ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8h_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_h_/acea_clepa_jama_kama_contribution_Ex_8h_20131104.pdf; last accessed 14.11.2013

ACEA et al. 2013c ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA, KAMA Answers_Questionnaire-1_Exe-8h_20131220.pdf" received via e-mail on 20.12.2013 by Otmar Deubzer, Fraunhofer IZM, from Peter Kunze, ACEA

ELV Directive	Directive 2000/53/EC of the European Parliament and of the Council, Annex II, consolidated version from 11.06.2013, available under: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20130611:EN:PDF
Oeko-Institut 2010	Zangl, S., Blepp, M., Deubzer, O., Gensch, C., Hendel, M., Liu, R. (2010), Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, Oeko-Institut e.V. in cooperation with Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM), retrievable from https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 05.09.2013

8.0 Exemption 8(j) “Lead in solders for soldering in laminated glazing”

Abbreviations and Definitions

CTE	Coefficient of thermal expansion
OEM	Original equipment manufacturer, here: vehicle manufacturers
PVB	Polyvinyl butyral
R&D	Research and development
SOP	Start of production
SUV	Sport utility vehicle
Tonne	Metric tonne corresponding to 1,000 kg

Declaration

The phrasings and wordings of stakeholders’ explanations and arguments have been adopted from the documents provided by the stakeholders as far as possible. Formulations have been altered only in cases where it was necessary to maintain the readability and comprehensibility of the text.

8.1 Description of the Exemption

ACEA et al.[210] requests the continuation of Exemption 8(j) in Annex II of the ELV Directive:

Lead in solders for soldering in laminated glazing

ACEA et al.[211] suggests to review the exemption at the earliest in 2017.

8.1.1 History of the Exemption

The exemptions related to the use of lead in solders for soldering on or in automotive glazing have been reviewed several times since 2007. Until 2009, the use of lead in solders for soldering on glass and in laminated glazing fell under the scope of the

---

[210] ACEA et al. (2013a) ACEA, CLEPA, JAMA, KAMA stakeholder document “acea_clepa_jama_kama_contribution_Ex_8j_comprehensive_answers_20131104.pdf”, submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/acea_clepa_jama_kama_contribution_Ex_8j_comprehensive_answers_20131104.pdf; last accessed 10.01.2014

[211] Ibid.

former Exemption 8: "Lead in solder in electronic circuit boards and other applications" in Annex II of the ELV Directive[212], which was valid at that time. During the 2007/2008 review, a stakeholder, Antaya, claimed to have a solution for lead-free soldering on glass. In 2007, Antaya had applied for repealing the exemption as they claimed to have a viable solution to substitute the lead-containing solders. Glass makers and vehicle manufacturers opposed Antaya's arguments and views. During the review process, the available stakeholder comments did not provide a basis for a clear recommendation to repeal the exemption. The general exemption for lead in solders was thus further specified, and soldering on glass incl. soldering in laminated glazing was covered by Exemption 8(b)[213]:

> *Lead in solder in electric applications on glasses*

The exemption was reviewed in 2009/2010 again[214], and the exemption was split into two parts:

> *8(i) Lead in solders in electrical glazing applications on glass except for soldering in laminated glazing in vehicles type approved before 1 January 2016;*

and

> *8(j) Lead in solders for soldering in laminated glazing; review in 2014;*

There was no evidence that the proposed indium-based lead-free solder may be viable for soldering in laminated glazing. Oeko-Institut[215] therefore recommended *"[...] to exclude soldering in laminated glass from the ban of lead until there is evidence that a solution is available. To promote the technical and scientific progress towards a lead-free solution, it is recommended to review this exemption in 2014. The stakeholders will then have to show that they have undertaken steps to achieve compliance with the material bans in the ELV Directive."*

---

[212] Cf. Directive 2000/53/EC (ELV Directive), Annex II, exemption 8: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:269:0034:0042:EN:PDF; last accessed 24.01.2014

[213] For details see page 45 ff of Oeko-Institut (2008) Stéphanie Zangl, Oeko-Institut e.V.; Otmar Deubzer, Fraunhofer IZM: Adaptation to Scientific and Technical Progress of Annex II Directive 2000/53/EC, final report from January 2008, Oeko-Institut e. V., Fraunhofer IZM; download from http://circa.europa.eu/Public/irc/env/elv/library?l=/stakeholder_consultation/evaluation_procedure/reports/final_report/report_revision/_EN_1.0_&a=d;

[214] For details see page 151 ff of Oeko-Institut (2010) Zangl, S.; Hendel, M.; Blepp, M.; Liu, R.; Gensch, c: (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28 July 2010, retrievable rom https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 24.01.2014

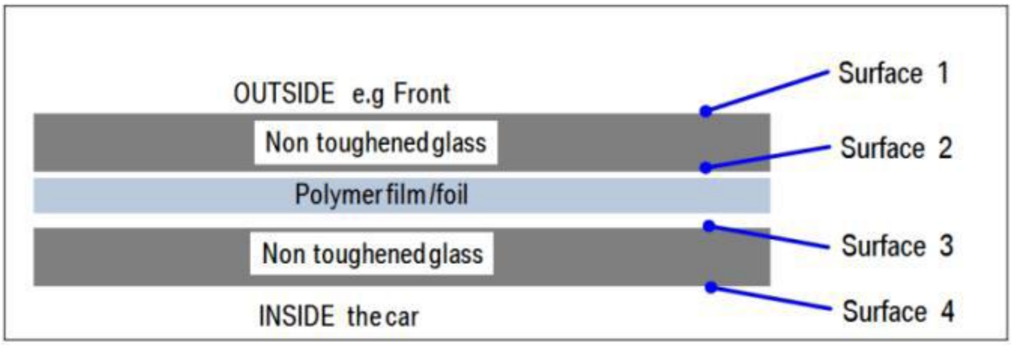
[215] Ibid.

The Commission followed the recommendation and set a review date for 2014 in Exemption 8(j) so that the exemption has become due for review. Exemption 8(i) was last reviewed in 2011/2012, and the wording of this Exemption was confirmed so that no changes became apparent regarding the wording of Exemption 8(j).[216]

8.1.2 Technical Background

ACEA et al.[217] explains that in laminated glazing structures, a polymer layer is embedded between two thinner panes of glass as illustrated in Figure 8-1.

Figure 8-1: Structure of Laminated Glazings



Source: BMW, quoted in ACEA et al.[218]

According to ACEA et al.[219], soldering of laminated glazing structures may be applied on a silver print on the non toughened glass, or on the silver print on top of the black lead-free enamel print of the glass, or to wires/films inside/on the foil. Wire materials are tungsten or copper.

---

[216] Oeko-Institut (2012) Deubzer, O. (Fraunhofer IZM); Zangl, S, (Oeko-Institut); Adaptation to Scientific and Technical Progress under Directive 2000/53/EC (ELV Directive) - Review of exemption 8 (i), Final Report, Freiburg, 10 March 2012; retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Exe_8_i_2011/ELV_Exemption_8i_final_report_March_2012.pdf; last accessed 10.01.2014

[217] Op. cit. ACEA et al. (2013a)

[218] Op. cit. ACEA et al. (2013a)

[219] Op. cit. ACEA et al. (2013a)

ACEA et al.[220] lists typical uses of lead containing solders within laminated glazing structures[221]:

1) Heating Applications

   a) Heated Wire Windshield or Backlight
   The technology is used to defrost/defog the entire windshield or backlight. Thin tungsten wires are embedded onto the interlayer materials (e.g.: polyvinyl butyral (PVB)) with solder connections to copper strip busbars. All is assembled between two plies of glass.

   b) Heated Coated Windshield
   The technology is used to defrost/defog the entire windshield. A metallic coating is heated by an electrical current. The electricity is applied through connectors soldered/ welded on busbars in contact with the coating. All is assembled between two plies of glass including an interlayer material (e.g. PVB).

   c) Heating pattern on backlight
   The technology is used to defrost/defog the laminated backlight. A silver print conductive pattern is printed on the occupant compartment side surface. Connections are soldered to the silver print busbar on glass.

   d) Heating Device Circuit on surface 4
   The technology is used to defrost the windshield on a local surface, for instance a heating pattern for camera area on windshield. A silver print conductive pattern is printed on the occupant compartment side surface. A connector is soldered to the silver print pattern on glass.

   e) Windshield Wiper De-icer Wire
   The technology is used to defrost the windshield wiper area in rest position. Thin tungsten wires are embedded onto the interlayer materials (e.g. PVB). Connectors are soldered to the busbar plate in a local area at the edge of the screen. Then connectors are covered by sealant.

   f) Windshield Wiper De-icer Printed
   The technology is used to defrost the windshield wiper area in rest position. Silver ceramic grid lines are printed on inner glass surface and heated up by an electrical current. Connectors are soldered to the silver ceramic busbar in a local area at the edge of the screen. Then connectors are covered by sealant.

---

220 ACEA et al. (2013b) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8j_further_Input_Public_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/acea_clepa_jama_kama_contribution_Ex_8j_further_Input_Public_20131104.pdf; last accessed 10.01.2014

221 The various applications were sorted and grouped by the consultants to improve the overview and comprehensibility of the information provided by ACEA et al. (2013b)

2) Antenna Applications:

   a) Wire Antenna
      The technology is used for radio/TV reception system on windshield. A metallic wire (usually made of copper) is embedded on the surface of the interlayer material (e.g. PVB) that is between the two plies of glass. A connector is soldered to the metallic wire.

   b) Antenna Printed
      The technology is used for radio/TV reception system on windshield, laminated sidelight or laminated backlight. A silver print conductive pattern is printed on the occupant compartment side surface. A connector is soldered to the antenna on glass.

3) Capacitive Coupling Connectors Soldered on Position 4
   This is a new development which is the final stage of development and intended to be introduced in a pilot application into the European market during the year 2014. A capacitive coupling connector is soldered on side 4 but not directly connected with used silver structure reception inside the glass pair. The connector therefore interacts like a capacitor.

ACEA et al.[222] claims that for laminated automotive glazing structures covered by Exemption entry 8(j), the technologies and demands are different from soldering on toughened glass, which is covered by Exemption 8(i). Besides some pilot applications, lead-free soldered solutions for laminated glazing structures are still at the screening stage. The challenges for contacting electrical joints in laminated glass structures are component and vehicle specific to a high degree.

ACEA et al.[223] say that as of today, the use of lead is still unavoidable for some applications for laminated glasses due to the facts that:

- Compared with toughened glasses, laminated glasses crack much easier when a certain stress is applied. The internal stress in laminated glass is not uniform and varies with the edge distance. Positive results with the same solder and connector can fail with the change of the position of the solder joint on the same glass.
- Compared with lead solders, lead-free solders give much higher stress to the glass to which the solders are attached.
- As a result, compared with toughened glasses, more advanced technologies are required to attach lead-free solders to laminated glazing structures - and to meet the specifications of the OEMs.

ACEA et al. put forward that the five years development of lead-free solders for single sheet toughened glass (Exemption 8(i)), as communicated in previous consultations, is nearly completed. Now there is intensified development capacity on establishing

---

[222] Op. cit. ACEA et al. (2013a)

[223] Op. cit. ACEA et al. (2013a)

available lead-free solders applications for laminated glazing in laboratory and later full-scale. ACEA et al.[224] claims that this challenge will require five more years at least, possibly more, for complete industrialization.

Antaya[225] presents a different point of view concerning the scope of Exemption 8(j) in demarcation of Exemption 8(i). Antaya[226] considers soldering between – not on - surfaces 2 and 3 as soldering in laminated glazings, while any contacts to the glass on surface 1 – in principle, as no soldering joints are applied on this surface - and on surfaces 2, 3 and 4 are considered to be soldering on glass, and as such, to be in the scope of Exemption 8(i), and not of Exemption 8(j). Antaya's detailed arguments are described in Section 8.2.1.1 on page 74.

8.1.3 Amount of Lead Used under the Exemption

According to ACEA et al.[227], electrical contacts in laminated glazing structures today are applied in a limited quantity of vehicles. In the future, e-driven vehicles will need this application in general, because of missing heat emission from an internal combustion engine.

As a basis for calculation, ACEA et al.[228] use actual market development figures from the supply chain. For each application group min./max. values for the applied lead content have been used and then the numbers have been multiplied with the amount of vehicles on the EU market using this equipment. Table 8-1 shows the calculation for the EU in detail. Figures worldwide have not been investigated due to time constraints.

---

[224] Op. cit. ACEA et al. (2013a)

[225] Antaya (2014a) Antaya Technologies Corporation document "Antaya Response to Questionnaire-2 Exe 8j.pdf", sent via e-mail by William Booth, Antaya Technologies Corporation, to Otmar Deubzer, Fraunhofer IZM, on 14.02.2014

[226] Ibid.

[227] Op. cit. ACEA et al. (2013a)

[228] Op. cit. ACEA et al. (2013a)

Table 8-1: Calculation of Lead Use under Exemption 8(j) in the EU

	Lead per vehicle min; [g]	Lead per vehicle max; [g]	No of vehicles with application/y	Total min. [kg]	Total max. [kg]
Wired Heated	0,04	0,06	1200000	48	72
Wire Antenna	0,05	0,1	380000	19	38
Wire Heated Wiper Rest Area	0,63	1,5	84000	52,9	126
Printed Heated Wiper Rest Area	0,63	1,5	400000	252	600
Printed Heated Backlights	0,42	1,75	200000	84	350
Printed Camera Window	0,1	0,2	1000000	100	200
Printed Antenna	0,1	0,42	200000	20	84
			total [kg]	575,9	1426
			total [tons]rounded	*0,6*	*1,5*
density Lead 11,36 g/cm³			*Volume [m³]*	*0,05*	*0,13*

Source: ACEA et al.[229]

For the EU market, ACEA et al.[230] see a total quantity of lead used under Exemption 8(j) applications in the range of 0.6 to 1.5 metric tonnes per year.

8.2 Stakeholders' Justification for or against the Continuation of Exemption 8(j)

8.2.1 Scope of Exemption 8(j)

Antaya and ACEA et al. have opposing views on the scope of Exemption 8(j) concerning which applications are covered by this exemption in demarcation from Exemption 8(i).

8.2.1.1 Scope of Exemption 8(j) According to Antaya

Antaya[231] finds it important to fully understand the distinction between applications falling under Exemption 8(i) and those falling under Exemption 8(j):

[229] Op. cit. ACEA et al. (2013a)

[230] Op. cit. ACEA et al. (2013a)

[231] Op. cit. Antaya (2014a)

8(i) Lead in solders in electrical glazing applications **on** *glass except for soldering in laminated glazing in vehicles type approved before 1 January 2016*

and

8(j) Lead in solders for soldering **in** *laminated glazing; review in 2014*

Antaya[232] states that the critical distinction between Exemption 8(i) and 8(j) is the word "in" (laminated glazing).[233] Antaya claims that the numerous references contained in *"ACEA Submission of Joint Associations to Stakeholder Consultation on Entry 8(j) and Supplemental information"* in fact relate to applications covered by Exemption 8(i). Antaya[234] illustrates its point of view related to applications, which ACEA et al. see to be covered by Exemption 8(j).

In Table 8-2 below, Antaya[235] explains its view on, which application covers, which exemption. The green marked fields indicate cases of coincidence of Antaya's point of view with that of ACEA et al.

---

232 Op. cit. Antaya (2014a)

233 For further clarification please refer to pages 181 and 182 of the 2010 final report; http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/Exemption_8j_Excerpt_in_Final_report_ELV_RoHS_28_07_2010.pdf; reference as provided by Antaya

234 Op. cit. Antaya (2014a)

235 Op. cit. Antaya (2014a)

Table 8-2: Applications in and out of Scope of Exemption 8(j)[236]

Application as Listed by ACEA et al. to be in the Scope of Exemption 8j	According to Antaya Covered by Exemption No.
Wire heated windscreens with wires embedded into/on the foil between the two glass plies	8(j)
Printed heated device circuit on the inner surfaces of the windscreen (surface 2 or surface 3)	8(j) except when inner surface is exposed
Antenna or sensor wire products (wires embedded into/on the foil)	8(j)
Connection joints to electrically conductive films within the laminate	8(j)
Printed antenna device circuit on laminated glass surface 4	8(i)
Printed heated circuits on laminated glass surface 4	8(i)
Wire heated wiper rest area windscreens	8(i)
Capacitive coupling connectors soldered on position 4	8(i)

Source: Antaya[237]

Antaya[238] considers only the below two sub-categories as soldering "in" laminated glass applications:

- Wire heated applications, both for heated backlights and wiper rests where the soldered connection is made between the connector and a conductive foil, which is attached to a tungsten copper wire embedded in the polyvinyl butyral interlayer (PVB).
- Wire antenna applications, where a tungsten copper wire embedded in the PVB is soldered to the connector to provide signal reception.

---

[236] For the numbering of the surfaces see Figure 8-1 on page 59

[237] Op. cit. Antaya (2014a)

[238] Op. cit. Antaya (2014a)

8.2.1.2 Scope of Exemtion 8(j) According to ACEA et al.

ACEA et al.[239] bases its scope considerations on the report of Oeko-Institut[240]. On page 181, the first sentence is *"Soldering in laminated glazing was excluded from Joint Test Program"*, and further deductions are built on this statement. According to ACEA et al.[241], any soldering in laminated glazing applications was excluded from the Joint Test Program, "in" as well as "on". For ACEA et al. [242] this becomes even clearer with the next sentences, namely: *"Antaya had not tested its solder for this application. ... Antaya ... would need the glass makers' support for the supply of the laminated glass"*.

ACEA et al.[243] claims that the Test Program did not consider any kind of application of solder to laminated glazing. So the logical conclusion is that "in laminated glazing" has to be understood as "in laminated glazing applications". Differences between laminated and tempered products have been addressed in the previous reports (e.g. Oeko-Institut (2008) p. 60), but have not been detailed because there was common understanding at that time that laminated glass is out of scope for technical reasons.

ACEA et al.[244] highlights that in this instance the interpretation of the word "in" is critical. They explain that in the quoted reference[245] it seems that Antaya may have interpreted it as meaning wires inside laminated glass. The industry has interpreted it as meaning anything related to laminated glass and soldered connectors. It is obvious that there have been different interpretations of the wording in Exemption 8(j). To clarify the position for the automotive industry, ACEA et al.[246] suggests that this exemption could be redefined as part of the review. There are three distinct groups of automotive glass products:

- Printed toughened glass (covered by Exemption 8(i));
- Printed non-toughened laminated glass; and
- Laminated glass with foils or wires inside (covered by Exemption 8(j)).

[239] ACEA et al. (2014c) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, JAMA, KAMA Comments on ANTAYA statement on Exe-8(j)_20140507.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 08.05.2014

[240] Op. cit. Oeko-Institut (2010)

[241] Op. cit. ACEA et al. (2014c)

[242] ACEA et al. (2014a) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, JAMA, KAMA Answers_Questionnaire-2_Exe-8j_20140404-rev.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 24.04.2014

[243] Ibid.

[244] Op. cit. ACEA et al. (2014c)

[245] Op. cit. Oeko-Institut (2010)

[246] Op. cit. ACEA et al. (2014c)

ACEA et al.[247] states that all of the above glass products have differing technical challenges and require different solutions. Glass producers confirm the critical aspect of soldering on glass without lead and furthermore when glass is non-toughened in a laminated structure. There is therefore a paradox to consider that this most critical case (i.e. solder on non-toughened glass in a laminated structure) would have been included in the 8(i) Exemption with a termination date on Jan 1st 2016. ACEA et. al.[248] considers Exemption 8(j) applicable to a-non toughened laminated glass system (including solders in between the two sheets of glass or solders on the surface of non-toughened laminated glass).

8.2.2 Status of Substitution or Elimination of Lead According to ACEA et al.

ACEA et al.[249] states that, generally, lead is required to match the different coefficients of thermal expansion (CTE) of the materials used in laminated glazing structures (i.e. the mechanical stress-sensitive glass, the solder material and the connector) to avoid a glass failure by cracking. Since soldering is carried out at high temperature, the CTE mismatch, for example between the glass and the solder while cooling needs to be compensated by the ductility of the solder.

ACEA et al.[250] justify the continued use of lead as follows:

- Currently there is no sufficient, sustainable, lead-free solder available providing the high ductility of lead-containing solder (that fulfils the requirements of OEMs), especially since glass panes used for laminated glass are thinner and non-toughened resulting in higher glass crack sensitivity. In addition there are limitations in temperature process windows.
- No failure of the electric contacts in laminated glazing structures during vehicle lifetime is acceptable because this would directly affect vehicle safety aspects. Any potential substitute has to prove at least the same performance as the current solution.
- For some components, emerging solutions for the contacting inside the foil are on the way, but in general, and for the majority of applications, lead-free solders are still subjects of intensive R&D efforts. Testing has confirmed repeatedly that lead-free solders fail to fulfil the customer specifications. This is valid for in laminate soldering, where first solutions are available and complete industrialization needs sufficient implementation time. Particular challenges are faced when soldering laminated glass panes with structure contacts (e.g. silver prints) either directly on the glass or on top of a ceramic layer.

---

[247] Op. cit. ACEA et al. (2014c)

[248] Op. cit. ACEA et al. (2014c)

[249] Op. cit. ACEA et al. (2014a)

[250] Op. cit. ACEA et al. (2014a)

- The global supply chain cannot provide lead-free solutions for entry 8(j), which sufficiently fulfil the specifications of the OEMs. Due to efforts dedicated to tempered glass solutions, and the lack of validations by OEM's glass-makers, ACEA et al.[251] state in their contribution that they had no possibility of evaluating soldering on surface 2, 3 and 4 of laminated glazing structures at the time.
- Technical production situation is not capable / given that a technical solution has not yet been verified and therefore it is not feasible to identify investment requirements.
- The principal application of lead-based solders in laminated glazing structures is currently required to enable (reliable electrical contacting) production of:
    - Fine Wire Heating Grid (for de-icing of the entire windshield);
    - Local coating and printing on position 2 and 3 (for windshield de-icing frozen wipers);
    - Local printing on position 4 (for antenna on windshield for radio, TV systems or alarms and sensors);
    - In general silver prints on surface 2, surface 3 and surface 4;
    - Contacts on position 4 of laminated glazing structures for reliable contacts to antenna, heating, alarm or sensor circuits.

ACEA et al.[252] claims that OEMs have been evaluating new solutions for toughened glass since 2008, with big failures during the first years, and they have been constantly in contact with their glass-makers. Because of the timing of the expiry of Exemption 8(i), the successful development of lead-free solders for that application has been the priority. This is still on-going. When the remaining challenges, e.g. of industrialization, have been met, the experiences can be used for development of entry 8(j), i.e. non-toughened glass issues.

ACEA et al. contend to have tested the following connectors/lead-free solders since 2008, which all failed to meet the requirements:

- Customer specified connectors with Pb-free solders:
    - 96.5Sn3.5Ag;
    - 42Sn57Bi1Ag;
    - 88Sn8In0.5Bi3.5Ag;
    - 92.5Sn4Bi3.5Ag).
- Flexible foil connectors with Pb-free solders:

[251] Op. cit. ACEA et al. (2014a)

[252] Op. cit. ACEA et al. (2014a)

    - 98Sn2Ag;
    - 55In2.5Ag42.5Sn.
- Stainless steel connectors with Pb-free solders:
    - 96.5Sn3Ag0.5Cu;
    - 42Sn57Bi1Ag;
    - 98Sn2Ag.
- Directly soldered wires to the print with Pb-free solders:
    - 98Sn2Ag;
    - 57Bi42Sn1Ag;
    - 55In2.5Ag42.5Sn;
    - 90In10Ag;
    - 65In30Sn4.5Ag0.5Cu;
    - 90Sn7.5Bi2Ag0.5Cu.
- Alloys having a lower melting point than 96.5Sn3.5Ag for example, hence less stress to glass by soldering, and with a much less bismuth content than 42Sn57Bi1Ag, also understood as having bad thermodynamic effect on laminated glazing due to brittleness and CTE;
- In thermal cycle tests, ACEA et al.[253] found glass cracks with the following solders irrespective of connector type (copper, stainless steel, wires, foils):
    - 96.5Sn3.5Ag;
    - 42Sn57Bi1Ag;
    - 88Sn8In0.5Bi3.5Ag;
    - 98Sn2Ag;
    - 96.5Sn3Ag0.5Cu;
    - 90In10Ag.

According to ACEA et al.[254], the lead-free solders 55In2.5Ag42.5Sn and 65In30Sn4.5Ag0.5Cu do not produce glass cracks in thermal cycle tests, but they do not pass high temperature test requirements as specified in the German OEM test specification.

---

[253] Op. cit. ACEA et al. (2014a)

[254] Op. cit. ACEA et al. (2014a)

ACEA et al.[255] claim that positive R&D test results with lead-free solutions for some specific components will need further validation on vehicle level before a decision for volume production is feasible. The estimations vary between the end of 2016 and 2018, and depend on further positive component test results. As such, no concrete timing estimation is possible today.

Conductive gluing as a way to eliminate the use of lead is stated not to be an option for heating functions on surface S2 or S4 due to the current density they need; there is an inevitable compromise between mechanical resistance and conductivity. This presents technical barriers to developing applicable solutions that would even partially meet the OEM requirements, especially for durability. The technology is applied e.g. for embedded heated wires or heatable coated glass, but the conductivity is then stabilized by the pressure of glass panes assembled after auto-claving.

A technology screening has been made, to clarify if there are usable solutions in other industry sectors like photovoltaic cell production. Use of lead-based solder was found to be state of the art there as well, and a transferable and broadly applicable lead-free solution could not be identified.

8.2.3 Status of Substitution or Elimination of Lead According to Saint-Gobain Sekurit

8.2.3.1 Overview on Soldering on Laminated Glazings

Sekurit[256] presents the following applications of soldering on laminated glazings depending on the material that is to be connected[257]:

1) Connections to wire pattern:
   - A) Wire heated windscreens (W wires embedded into/on the foil);
   - B) Antenna or sensors wire products (Cu wires embedded into/on the foil);
   - C) Wire heated wiper rest area windscreens (Cu wires embedded into/on the foil).
2) Connections to conductive layer:
   - A) Connections to electrically conductive films within the laminate.
3) Connections to printed pattern:
   - A) Printed heated device circuit on surface 2, 3 (inner surfaces of the windscreen);

[255] Op. cit. ACEA et al. (2014a)

[256] Sekurit (2014b) Saint- Gobain Sekurit document "2014-02-06_Saint Gobain_Lead-Free Soldering on laminated glass_external.pdf", sent via e-mail by Volker Offermann, Sekurit Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 06.02.2014

[257] For a list of functionally ordered applications see Section 8.1.2 on page 50

B) Printed heated circuits on surface 4;

C) Printed antenna device circuit on surface 4.

Sekurit[258] explains its strategy to enable lead-free soldering in the above applications.

- A lead-free solder has been developed;
- Flat connectors are especially developed to be applied on less robust non-tempered glass;
- Button and crimp connector properties have been adapted and optimized to reduce the mechanical impact on the glass as far as possible;

Sekurit[259] presents an overview of the lead-free solutions for the above applications.

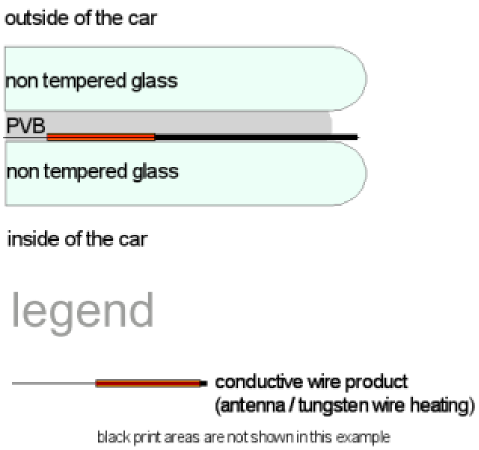
8.2.3.1.1 Lead-free Solutions for Connections to Wire Patterns

Applications based on connections to wire patterns according to St. Gobain (2014b) are:

1) antennae (copper wire)
2) camera defoggers (copper wire)
3) wiper park heaters (copper wire)
4) ice control wires (tungsten wire)

Figure 8-2 shows an outline of this technology.

Figure 8-2: Schematic View of Connections to Wired Patterns in Laminated Glazings



Source: Sekurit[260]

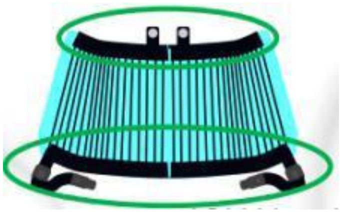
[258] Sekurit (2014a) Saint- Gobain Sekurit document "2014-02-03_Questionnaire-2_Exe-8j_St – Gobain.pdf", sent via e-mail by Volker Offermann, Sekurit Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 03.02.2014

[259] Op. cit. Sekurit (2014b)

[260] Op. cit. Sekurit (2014b)

Sekurit[261] describes that the wires are stepped onto the PVB foil and are then contacted with lead-free solder via ribbon busbars/flat connectors (Figure 8-3) prior to the lamination process.

Figure 8-3: ICW Busbar (Ribbon Busbar/Flat Connector



Source: Sekurit (2014b)

According to Sekurit[262], this lead-free solution is lab-validated and validated at the industrial line, but there is no serial implementation yet due to higher costs of this technology compared to the lead-soldered solution.

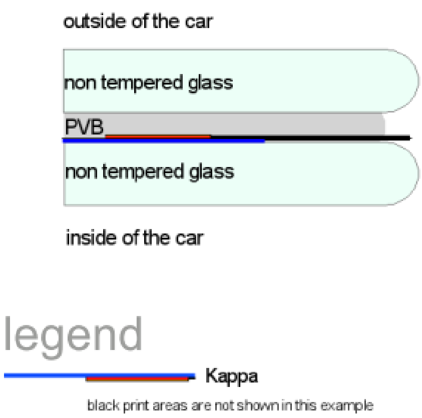
8.2.3.1.2 Lead-free Connections to Conductive Layers

Figure 8-4 shows an outline for soldering on conductive layers.

Applications requiring connections to conductive layers are antennae and heating "grids" (Figure 8-5), which Sekurit[263] manufactures using flat connectors.

According to Sekurit[264], this lead-free solution using flat connectors is already in serial production since 2013.

Figure 8-4: Lead-free Connections to Conductive Layers



[261] Op. cit. Sekurit (2014b)

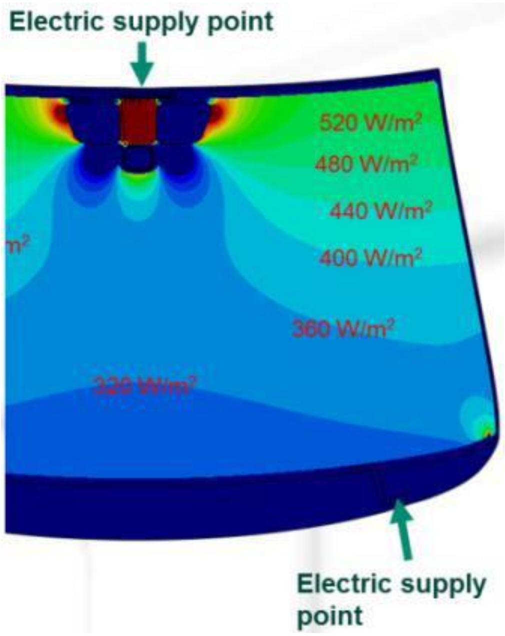
[262] Op. cit. Sekurit (2014b)

[263] Op. cit. Sekurit (2014b)

[264] Op. cit. Sekurit (2014b)

Source: Sekurit[265]

Figure 8-5: Contacted Heating Grid



Source: Sekurit[266]

Sekurit[267] specified examples, which are already applied in the field:

i. Mercedes VS20 (flat connector for antenna),

ii. Ford CD 391 (flat connector to contact ICW busbar, development 2010, delayed start of production (SOP) 2013).

iii. VW Passat 470 and Golf 370 (ICC) developed in completely lead-free.

Silver print on glass is contacted with a lead-free busbar. Finally, the flat connector for contacting this busbar has been taken over as identical part from former model (with Pb solder) to save costs.

8.2.3.1.3 Connections to Printed Patterns

8.2.3.1.3.1 Connections on and in Windscreens

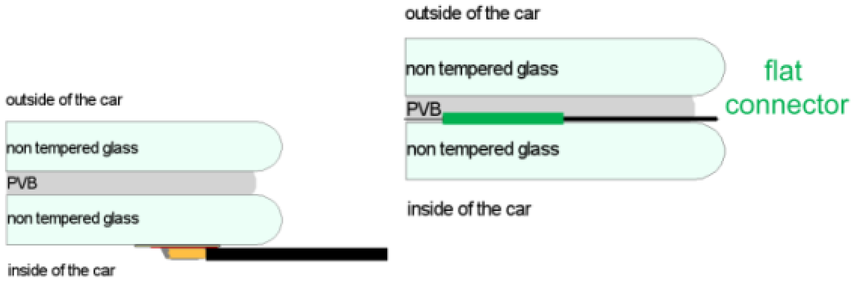
Figure 8-6 shows the principle of connections to printed patterns on windscreens.

[265] Op. cit. Sekurit (2014b)

[266] Op. cit. Sekurit (2014b)

[267] Op. cit. Sekurit (2014b)

Figure 8-6: Outline of Connections to Printed Patterns on (left) and in Windscreens

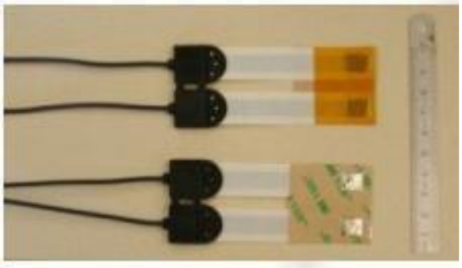


Source: Sekurit[268]

Sekurit[269] lists the following applications:

1) Antennae on windscreens
2) Camera defoggers
3) Wiper park heaters

Figure 8-7: Flat Connectors for Contacting Wiper Park Heaters



Source: Sekurit[270]

Sekurit[271] claims that this lead-free solution has been applied in series in laminates for two years already (since 2012 latest) using flat connectors for contacting printed silver busbars and ribbon busbars.

---

[268] Op. cit. Sekurit (2014b)

[269] Op. cit. Sekurit (2014b)

[270] Op. cit. Sekurit (2014b)

[271] Op. cit. Sekurit (2014b)

Figure 8-8: ICW Ribbon Busbar/Flat Connector (left) and Crimp (right) and Button (left) Connectors

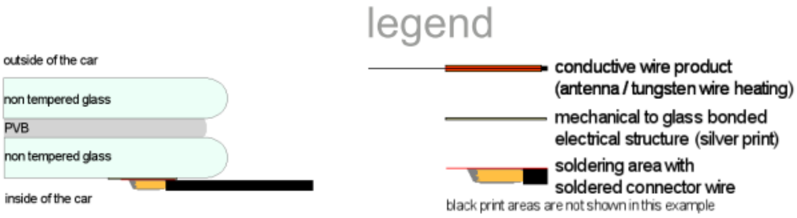
Source: Sekurit[272]

For soldering on laminates, the lead-free solutions are lab-validated using flat connectors and crimp and button connectors, which exert less mechanical forces to the glass.

8.2.3.1.3.2 Connections on Backlights

Figure 8-9 illustrates connections to printed patterns on backlights.

Figure 8-9: Outline of Connections to Printed Patterns on Backlights



Source: Sekurit[273]

Such connections are used for heating grids and antennae on backlights, according to Sekurit[274]. Sekurit[275] uses flat connectors like those for contacting wiper park heaters (Figure 8-7) to produce such connections.

Sekurit[276] claims that the lead-free flat connector and the lead-free button solutions on laminates are both lab-tested.

Sekurit[277] says that bridge connectors are sometimes used to contact printed patterns on laminated glass. Sekurit[278] has banned such connectors from use on

[272] Op. cit. Sekurit (2014b)

[273] Op. cit. Sekurit (2014b)

[274] Op. cit. Sekurit (2014b)

[275] Op. cit. Sekurit (2014b)

[276] Op. cit. Sekurit (2014b)

[277] Op. cit. Sekurit (2014b)

[278] Op. cit. Sekurit (2014b)

laminated glass irrespective of whether the connections are soldered with lead-containing or lead-free solders, because the bridge connectors exert too strong a mechanical stress to the glass.

8.2.3.2 Detailled Status and Applications of Lead-free Soldering

Sekurit[279] describes the status of its lead-free soldering programs for the various laminated glazing applications in more detail. The surface numbering is taken from Figure 8-1 on page 70.

1) Electrical Connections on Surface (2) and 3

   - Electrical Connections in Laminated Glazings to Silver Printed Busbars by Flat Connectors

     - Applications:
       Connection to coatings via printed busbar or complete silver printed structures (antenna, heating,…). Sekurit[280] states that, as a general rule, the manufacturer does not solder on surface 2. According to Sekurit[281], in terms of connection technology there is no difference between connections to side 2 and 3.

     - Status:
       - Development finished and ready for series, i.e. every car manufacturer sending a request for quotation will obtain an offer for serial application.
       - Lab-validated and industrially developed for laminated glasses heated by coating in the frame of industrial car projects (VW Passat 470 and Golf 370).
       - Other applications are fully analogue.

     - Reference:
       - Up to now no serial reference.
       - Mentioned models equipped with Pb-containing take-over parts to save costs for initial connector development.

2) Electrical Connections Between Surfaces 2 and 3 to Structures on or in the PVB Foil

   - Electrical Connections in Laminated Glazings to Single Wires or Ribbons on PVB Foil by Flat Connectors:

---

279 Sekurit (2014c) Saint- Gobain Sekurit document “2014-05-23_Questionnaire-4_Meeting-Follow-up_Sekurit_final.docx”, sent via e-mail by Klaus Schmalbuch, Sekurit Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 23.05.2014

280 Op. cit. Sekurit (2014b)

281 Op. cit. Sekurit (2014c)

- Application:
  Contact to wire antenna or to ribbon busbar (e.g. laminated glass heated by several wires – heating application for windshield, compare the below connections to several wires on PVB foil by ribbon busbars).
- Status:
  Development finished and ready for series, i.e. every car manufacturer sending a request for quotation will obtain an offer for serial application.
- Reference:
  Serial references and serial developments:
  - Mercedes VS20;
    Flat connector to contact antenna;
  - Ford CD 391;
    Flat connector to contact ribbon busbar of a windshield heated by several wires. Busbar itself is today still with Pb for economic reasons. Substitute without lead is developed at industrial level;
  - Volvo;
    Flat connector to contact ribbon busbar of windshields heated by several wires in serial development;
    - Volvo V526 with SOP CW (calendar week) 05/2015;
    - Volvo V541 with SOP CW 17/2016;
    - Volvo V542 with SOP CW 20/2016;
    - Volvo V543 with SOP CW 46/2016.

➢ Electrical Connections in Laminated Glazings to Several Wires on PVB Foil by Ribbon Busbar:

- Application:

  Contact of ribbon busbar to heating wires for laminated glasses heated by several wires – heating application for windshield.
- Status:
  Lab and industrially validated.
- Reference:

  Serial developments:
  - Volvo in serial development (busbar to contact several wires of a wire heated windshield);
  - Volvo V526 with SOP CW 05/2015;
  - Volvo V541 with SOP CW 17/2016;
  - Volvo V542 with SOP CW 20/2016;
  - Volvo V543 with SOP CW 46/2016.

3) Electrical Connections on Surface 4:

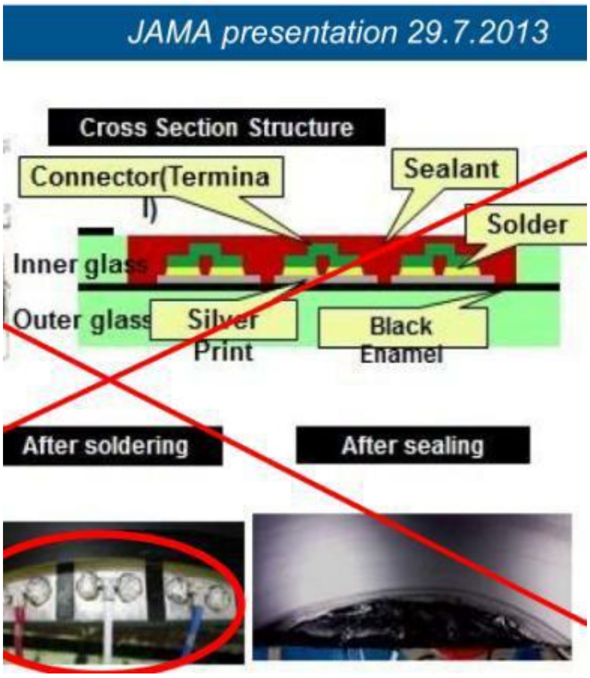
- Electrical Connections on Laminated Glazings to Heating Applications by Flat Connectors:
  - Applications:
    - Wiper park heater on windscreen;
    - Heating grid on backlight.
  - Status:
    Lab-validated, see Appendix A.3.0.
  - Reference:
    Up to now no serial reference.
- Electrical Connections on Laminated Glazings to Low Power Applications:
  - Applications:
    - Antenna;
    - Camera window defogger, etc.
  - Status:
    - Flat connector;
    - Crimp or button connector.
  - Reference:
    - All versions lab-validated;
    - Some versions validated at industrial level;
    - Crimp solution on first industrial car project:
      - Volvo V526 with SOP CW5/2015 in development;
      - 3 further models follow 2016.

8.2.3.3 Explanations for the Exclusion of Soldering on Surface 2

Sekurit[282] identifies a chain of non-preferable technical solutions in the special case of connections to silver printed busbars on side 2 as presented in Figure 8-10.

[282] Op. cit. Sekurit (2014c)

Figure 8-10: Soldering on Surface 2



Source: Sekurit[283]

Sekurit[284] recommends more robust alternatives like using flat connectors. If the customer cannot agree on these alternatives, Sekurit (2014b) states that Sekurit itself will provide the imposed layout. The flat connector technology used by Sekurit to connect side 3 is also feasible for connections to side 2.

Sekurit[285] explains that stone impacts affect the inner glass much less than the outer since both outer glass and PVB foil act like buffer layers. Sekurit therefore avoids soldering to surface 2 as well as silver prints on side 2, which both weakens the outer glazing and, as a consequence, reduces the resistance against stone impacts. Sekurit avoids such a configuration when developing new products for its customers.

Sekurit[286] states that the manufacturer is fully aware that today many references in the market do have printing on side 2, mainly for heating purposes. Sekurit[287] claims that the same functionality can be reached also with a minor design change that moves the heating grid from side 2 to side 4. If, however, this design change is impossible for reasons related to the overall vehicle architecture, and the affected car

283 Op. cit. Sekurit (2014b)

284 Op. cit. Sekurit (2014c)

285 Op. cit. Sekurit (2014c)

286 Op. cit. Sekurit (2014c)

287 Op. cit. Sekurit (2014a)

makers are ready to accept the lower stone impact resistance, then Sekurit will make available also a lead-free connection to printed structures on side 2.

8.2.3.4 Saint-Gobain Sekurit's Conclusions

Sekurit[288] concludes that lead-free solutions are available for all applications around laminates, and that for Sekurit laminated products the continuation of Exemption 8(j) is not required.

Sekurit[289] underlines that for Sekurit, as a glass manufacturer, a SOP date in 2014 is possible without any problem. Regarding the car manufacturers' validation process, Sekurit[290] points out that it can provide lead-free prototypes immediately to any car manufacturer, so that the car manufacturer validation time can be kept to a minimum.

According to Sekurit[291], the industrialization will be planned as soon as the EU has decided when Exemption 8(j) will end. Sekurit[292] says that today, there is no benefit for OEMs to switch to lead-free soldering on laminates. The introduction of a new technique always coincides with risks, and cost for some of the mentioned technologies may be higher than those related to conventional systems containing lead. Sekurit[293] concludes that without a clear visibility of a lead-free need, the OEMs are not willing to pay for this. Sekurit[294] underpins this conclusion with the experiences related to Exemption 8(i)[295]. When it was unclear whether the exemption would be continued after 2012, the number of requests for lead-free connectors on tempered glasses increased enormously during the first half of 2013[296], whereas the request for lead-free connectors on laminated glass remained at a low level.

[288] Op. cit. Sekurit (2014b)

[289] Op. cit. Sekurit (2014a)

[290] Op. cit. Sekurit (2014a)

[291] Op. cit. Sekurit (2014a)

[292] Op. cit. Sekurit (2014a)

[293] Op. cit. Sekurit (2014a)

[294] Op. cit. Sekurit (2014a)

[295] Lead in solders in electrical glazing applications on glass except for soldering in laminated glazing

8.2.4 Status of Substitution and Elimination of Lead According to Antaya Technologies

8.2.4.1 Removal of Exemption 8(j)

Antaya[297] calls for the immediate removal of Exemption 8(j). Antaya[298] claims to have developed, tested, and to supply lead free solder alloys for use on and in automotive glass.

Antaya[299] highlights that:

- The indium alloy works in the lamination, whether soldering occurs adjacent to the inside surface of glass or the PVB;
- There are lead free high tin / bismuth "in lamination" programs in production that work well when the soldering occurs not adjacent to the inside surface of the glass (which is most of the time);
- Sekurit has a third solution that is publicly promoted.

Antaya[300] says that the author's lead free alloys are in use on millions of production OEM vehicles, and Antaya has tested its alloys for use in laminated glass successfully with its automotive glass customers. Antaya's lead-free solder has several demonstrated benefits over lead based solders for use in laminated glass, especially in regards to melting point and resistance to cracking. It submits that Exemption 8(j) should therefore be repealed.

8.2.4.2 Detailed Status of Lead-free Soldering According to Antaya

Antaya[301] claims that both for soldering on glass as well as for soldering in laminated glazing, lead-free solutions are available. Antaya was asked to explain in more detail the status of its various lead-free programs related to this exemption to allow the consultants to obtain a clearer picture of the current situation.

---

297 Antaya (2013a) Antaya Technologies Corporation stakeholder document "20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf; last accessed 10.01.2014

298 Antaya (2013b) Antaya Technologies Corporation document "20131101q_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Questionaire.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101q_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Questionaire.pdfhttp://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf; last accessed 10.01.2014

299 Op. cit. Antaya (2014a)

300 Op. cit. Antaya (2013a)

301 Op. cit. Antaya (2013b)

In the below listing, the uses of Antaya lead-free alloys are differentiated by the surface on or in between which the solder alloys are applied, regardless of the interpretation whether this is considered in or outside of the scope of Exemption 8(i). Antaya's scope interpretation for the below listed applications is added in footnotes.

1) Soldering applications on surface 4[302]:
    - Ford Thunderbird (North America);
        - Pre-soldered copper terminal;
        - Lead free 65% Indium solder released for volume production;
        - In production from 2000-2005, no warranty claims related to the solder;
        - Lead free solder was specifically requested to solve cracking issues that were occurring with lead based solder.
    - GM U Vans (North America (Chevrolet Venture, Oldsmobile Silhouette, Pontiac Trans Sport) and Europe (Opel/Vauxhall Sinatra));
        - Pre-soldered copper terminal;
        - Lead free 65% Indium solder released for volume production to fix cracking problems with lead solder connectors;
        - In production 2000-2008, no warranty claims related to the solder.
    - Global vehicles:
        - Pre-soldered copper terminal;
        - Asian SUV (sports utility vehicle);
        - Start of production February 2016;
        - Validated with 65% indium solder to comply with the ELV Exemption 8(i) which is due to expire December 2015.
    - Global vehicles:
        - Windshield camera heater and heated wiper rest connectors;
        - European large SUV;
        - Start of production spring of 2016;
        - Validated with 65% indium solder to comply with the ELV Exemption 8(i) which is due to expire December 2015.

[302] According to Antaya (2014b) Antaya Technologies Corporation document "Antaya_Response_Meeting-2014-05-09.pdf", sent via e-mail by William Booth, Antaya Technologies Corporation, to Otmar Deubzer, Fraunhofer IZM, on 19.05.2014; covered by Exemption 8(i)

2) Surface applications on surface 2[303]:

- Global vehicle:
  - Pre-soldered copper terminals for heated wiper rest;
  - Lead free 65% Indium solder released for volume production;
  - Has been running in high volume production beginning in March 2013.
- Global Vehicle:
  - Pre-soldered copper terminal;
  - Asian small SUV;
  - Start of production August 2016;
  - Validated with 65% Indium solder to comply with the ELV Exemption 8(i) which is due to expire December of 2015.
- Global vehicle:
  - Windshield heated wiper area;
  - European small SUV;
  - Will be lead free using 65% Indium solder;
  - Start of production July 2016.
- Global Vehicle:
  - Windshield antenna;
  - Asian Sedan;
  - Will use lead free 65% solder for 3 lead antenna;
  - Start of production September 2016.

3) Soldering applications between surfaces 2 and 3[304]:

- Global Vehicle:
  - Windshield antenna;
  - European SUV;
  - Part has gone through validation testing, production part approval process (PPAP) has been issued, production orders pending;

[303] According to Antaya (2014b), covered by Exemption 8(i)

[304] According to Antaya (2014b) this is the only application covered by Exemption 8(j)

        - Part uses 65% Indium solder;
        - Lead free was selected because of superior soldering performance in the plant, especially in respect to its lower melting point, which did not damage the PVB material.
    - Global vehicle:
        - Windshield antenna;
        - European SUV;
        - Part is transitioning from lead solder to lead free solder (65%) for demonstrated performance and yield improvements in the plant.
    - Global vehicle:
        - Windshield antenna;
        - European Sedan;
        - Part is transitioning from lead solder to lead free solder (65%) for demonstrated performance and yield improvements in the plant.

Antaya[305] claims that, as a result of the political nature of the ELV exemption review process, Antaya has been required to execute non-disclosure agreements with several glass manufacturers which precludes sharing successful test results, program information, and field data.

Antaya[306] says that the OEM and glass suppliers were purposely left anonymous for current programs, as, given Antaya's previous experience with ACEA, it feels that disclosing these details would jeopardize the continued production, as well as the planned use of lead free solder for these awarded programs. Antaya (2014b) claims that lead free programs were successfully launched and in production at VW Mexico on well over 500,000 vehicles without production problems or warranty claims, until members of ACEA became aware of the use of lead free solder, and forced the change back to lead for purely political reasons. Representatives of the glass suppliers and OEMs, under the umbrella of ACEA, are currently in opposition to the repeal of Exemption 8(j), while independently, these same OEMs and glass suppliers (as evidenced above) have launched, and continue to launch programs for both Exemption 8(i) and 8(j) in order to comply with the repeal of 8(i) and 8(j). According to Antaya[307], indium based solder is used both to solve technical problems as well as to comply with legislation.

---

[305] Op. cit. Antaya (2014a)

[306] Op. cit. Antaya (2014b)

[307] Op. cit. Antaya (2014b)

8.2.5 Roadmap to Substitution or Elimination of Lead

8.2.5.1 Roadmap of ACEA et al.

ACEA et al.[308] says that the generic roadmap towards ELV compliance is not different from the timeline requested for entry 8(i) in the last review[309]. The reason for that is that industry is more or less in a similar position as during the stakeholder consultation on entry 8(i) and the implementation time of an identified, valid solution - which is an ongoing issue- mainly depends on the positive test results needed on vehicle level.

ACEA et al.[310] states that, when the remaining challenges e.g. of industrialization have been met in the supply chain, the experiences can be used for development of entry 8(j) i.e. non-toughened glass issues, which is in their opinion even more challenging.

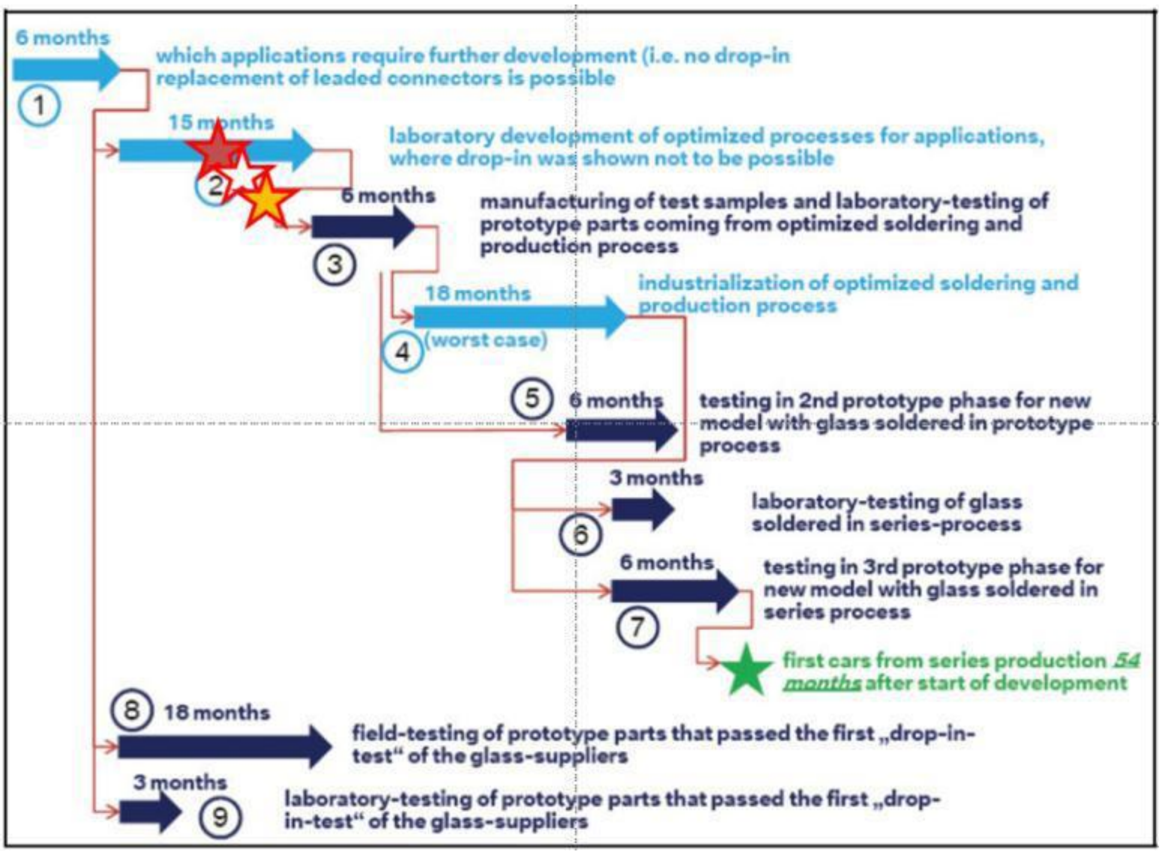
---

[308] Op. cit. ACEA et al. (2013a)

[309] For details see Oeko-Institut (2012)

[310] Op. cit. ACEA et al. (2013a)

Figure 8-11: Timeline for Soldering of Laminated Glass Structures and Soldering on Non-toughened Glass



Source: ACEA et al.[311]

ACEA et al.[312] contends that, based on solution availability on component level 48 to 60 months are necessary for validation on vehicle level and ramp up of production processes. ACEA et al.[313] states that the generic timeline given during the Entry 8(i) revision[314] is still valid and not repeated here again.

More practical experience with pilot applications is necessary to collect knowledge on long-term reliability as a prerequisite for volume production. A limited access to recently patented potential solutions may influence further progress speed as negotiations may be challenging.

The generic timeline for transition to replacement of lead-containing solder, provided by JAMA concerning laminated glass de-icer and antenna terminals as well, gives a

[311] Op. cit. ACEA et al. (2013a)

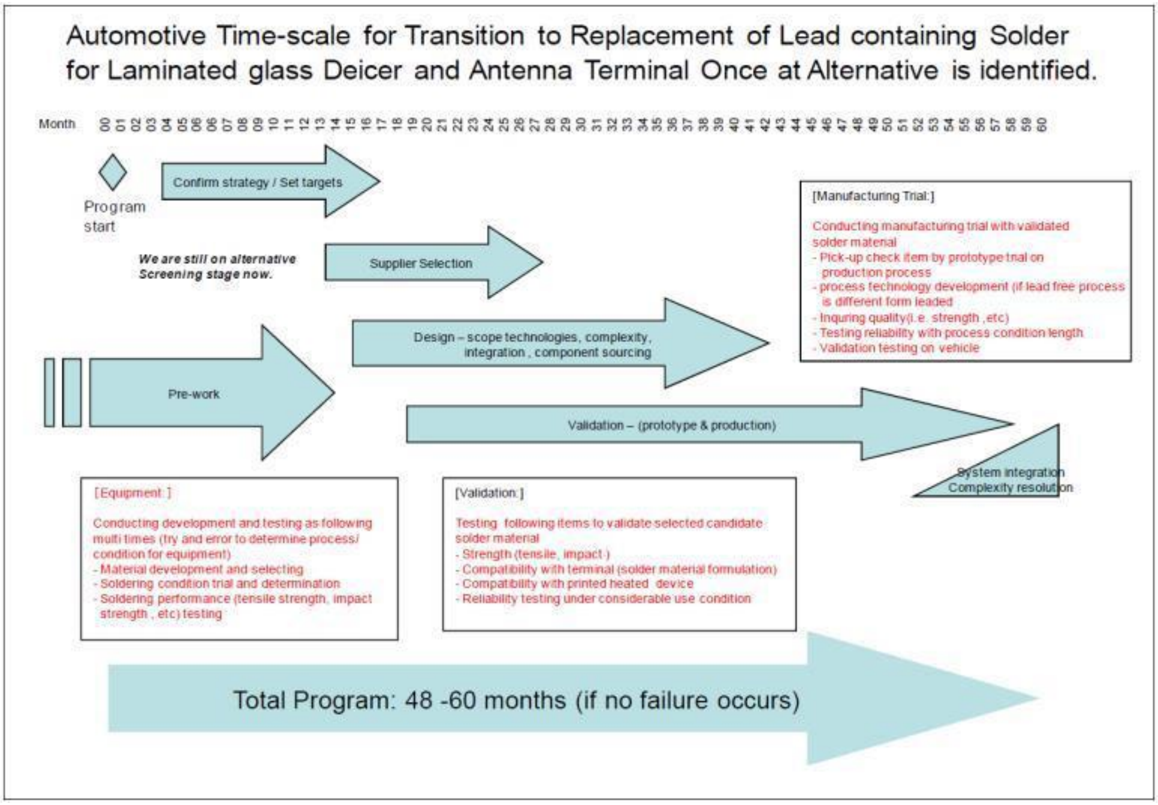
[312] Op. cit. ACEA et al. (2013a)

[313] Op. cit. ACEA et al. (2013a)

[314] For details see Oeko-Institut (2012), page 25 ff; source as referenced in ACEA et al. (2012a)

total program period of 48 to 60 months if no failures occur. It reconfirms that the overall timing in general is similar with the timeline shown in the above Figure 8-11 with the difference that the procedure of supplier selection requires more effort, resulting in an earliest implementation period of 48 months.

Figure 8-12: Timeline for Laminated Glass De-icer and Antenna Terminal



Source: JAMA, referenced in ACEA et al.[315]

ACEA et al.[316] states that today, numerous component and vehicle specific challenges still need to be tackled before a general volume production of lead-free soldered laminated glazing structures may be possible. Therefore ACEA et al.[317] suggests to continue the currently unlimited exemption and to have a review on the progress in 2017 at the earliest.

---

[315] ACEA et al. (2013a)

[316] ACEA et al. (2013a)

[317] ACEA et al. (2013a)

8.2.5.2 Saint-Gobain Sekurit

Sekurit[318] claims to have already developed technologies for lead-free soldering in/on laminated glass, and consequently a continuation of Exemption 8(j) is not required. Regarding soldering in laminated glass, the first serial solution has been brought to the market already in 2013, and today Sekurit[319] is developing various models with lead-free solutions. Sekurit[320] claims that all lead-free solutions are at least lab-tested. Further technical solutions have been validated already on industrial scale. Sekurit[321] will plan the industrialization as soon as the EU has decided when Exemption 8(j) will end.

8.2.5.3 Antaya Technologies

Antaya[322] takes issue with the claim of ACEA et al. asking for 5 years of development time justified by the suggestion that ACEA has spent 5 years developing the "Lead free solder for single sheet toughened glass". According to Antaya[323], its lead-free solution is in use in over 7 million instances, and it is the very same alloy and system that has been in use since 1998, in the United States. Antaya[324] blames ACEA for not having developed anything while Antaya[325] states that Antaya completed its development work in the 90's.

Antaya[326] states that between 1998 and 2014, the composition of the Indium alloy in wide use has not changed by even 0.1% of any element. The application / installation technology has not changed and the dimensions and functionality have not changed. Antaya[327] claims that the so called "development time" for lead free soldering has already consumed 16 years beyond the date it was in commercial use.

According to Antaya [328], its alloys have been fully industrialized and are in wide commercial use on all connector types for several high volume production vehicles.

---

318 Sekurit (2013b) Sekurit document "20131029s_Sekurit-Sekurit_contribution_ELV_Ex-8j_-Statement_FINAL.pdf", submitted during the online consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131029s_Sekurit-Sekurit_contribution_ELV_Ex-8j_-Statement_FINAL.pdf; last accessed 10.01.2014

319 Ibid.

320 Op. cit. Sekurit (2014a)

321 Op. cit. Sekurit (2013b)

322 Op. cit. Antaya (2014a)

323 Op. cit. Antaya (2014a)

324 Op. cit. Antaya (2014a)

325 Op. cit. Antaya (2014a)

326 Op. cit. Antaya (2014a)

327 Op. cit. Antaya (2014a)

328 Op. cit. Antaya (2014b)

Antaya[329] claims that the time for lead free validation for new OEM programs is 90 days or less, therefore no additional time is required for production readiness to justify continuing or delaying the removal of Exemption 8(j).

8.3 Critical Review

The conflicting views of ACEA et al., Antaya and Saint-Gobain Sekurit were discussed during the stakeholder meeting on 9 May 2014 at Fraunhofer IZM in Berlin. It became obvious that the current status of lead-free soldering in the various applications needs to be assessed in more detail. Statements of ACEA et al. that no reliable solutions are available do not adequately reflect the situation. It is also necessary to clarify the scope of the two Exemptions 8(i) and 8(j).

8.3.1 The Indium LCA Study by PE International

8.3.1.1 Compliance with ISO 14040 and ISO 14044

ACEA submitted the report "Indium Production - Life Cycle Assessment of the Indium Production Process" to this exemption review process. This LCA study was commissioned by ACEA and conducted by PE International, and is referenced here as PE (2012)[330]. The following is cited from the executive summary of the study[331]:

> "*The goal of this study is to show the environmental aspects of the production of indium… In summary, the results show that indium has a substantial environmental impact associated with its production… Based on this environmental profile of indium, Supplement B puts the impact of the production of indium into perspective through comparison with some other selected metals… The critical review confirmed the compliance of the methodology and report with ISO 14040/44. The verification of individual datasets and the comparison with other materials as shown in Supplement B were outside the scope of the review*".

PE[332] further states in the report that *"The study is prepared in accordance with ISO 14040/44. It is not intended to be used for comparative assertions intended to be disclosed to the public."*

---

[329] Op. cit. Antaya (2013b)

[330] PE International (2012), "Indium Production - Life Cycle Assessment of the Indium Production Process", commissioned by ACEA (European Automobile Manufacturers Association), stakeholder document "ISO report indium production 2012-05-22", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 25.04.2014, by Peter Kunze, ACEA

[331] Ibid.

[332] Ibid.

In item 5 of ISO 14044[333] a critical review is one of the aspects to be included in an LCA report, when the results of the analysis are to be communicated to any third party, i.e. an interested party other than the commissioner or the practitioner of the study. In case the study is a comparative assertion to be disclosed to the public, the aim of the critical review process is explained in item 6.1, also requiring that "*In order to decrease the likelihood of misunderstandings or negative effects on external interested parties, a panel of interested parties shall conduct critical reviews on LCA studies where the results are intended to be used to support a comparative assertion intended to be disclosed to the public*." The standard defines a 'comparative assertion' as an *"environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function"*.

The PE LCA study was submitted by ACEA et. al, in the course of the ELV evaluation of Ex. 8(j), in which indium based solders are a potential substitute for lead based solders. The report was reviewed by an external expert. This expert[334] confirms the compliance of the study with ISO 14040 and ISO 14044. However, in this regard, the review report states[335] that "*The review was performed according to paragraph 6.2. of ISO 14040 and ISO 14044, because the study is not intended to be used for comparative assertions intended to be disclosed to the public. This review statement is only valid for this specific report received on 11.05.2012 with the exception of Supplement B, which provides information which goes beyond the cradle-to-gate study of Indium.*" The reviewer thus took into account the limitations under which the report was prepared, excluding its use for public comparative assertions. As a consequence, the review statements on the ISO compliance of the study are correct.

ACEA et al., however, submitted the report to this public exemption review process in order to support the continued use of lead in laminated glazings according to the current exemption 8(j). In the consultants' point of view, as the study is publicly available, it could be used to <u>inform</u> about environmental burdens and impacts of indium mining and refining, and about environmental impacts of lead versus indium solders mentioned in supplement B of the report. However, it cannot be used to draw conclusions about the environmental superiority of lead solders compared to indium solders, as this implies that it is used as a public comparative assertion about the performance of lead solders and indium solders. Such use is contrary to the reviewed intended application given the study. In cases where results of an LCA are to be used to support comparative assertions intended to be disclosed to the public, paragraph

---

[333] ISO (2006), The International Organization for Standardization, ISO 14044-2006: Environmental management — Life Cycle Assessment — Requirements and Guidelines, published 2006, reviewed 2010.

[334] Finkbeiner (2014) Finkbeiner, M. (TU Berlin); Critical Review of the Study "Life Cycle Assessment of Indium Production", commissioned by ACEA (European Automobile Manufacturers Association), stakeholder document "ISO report indium production 2012-05-22_Summary+CR.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 25.04.2014, by Peter Kunze, ACEA

[335] Ibid.

6.1 of ISO 14044 requires among others: *"a panel of interested parties shall conduct critical reviews"*[336] *on the LCA study.*

Thus, in the consultants' opinion, using the views expressed in the study as comparative assertions, for concluding as to the environmental superiority of lead solders over indium solders, would be different from the studies intended and reviewed type of application. Such use would require that *"a panel of interested parties shall conduct critical reviews"* of the study. The reviewed study is thus understood not to be appropriate for such use in this public exemption review process.

Adding to this, *supplement B of the study was not subjected to the review process.*[337] Supplement B of the report compares environmental impacts of one kilogram of indium and lead, and volume equivalent amounts of indium and lead solder. Neither the conclusions of this part of the study, nor the underlying datasets for lead were subject to the review, nor is it mentioned that they had been subject to any other review process.

The consultants have thus not taken into account the PE[338] LCA study submitted by ACEA. Arguments of Teck[339] and of Indium Corporation[340] and Indium Corporation[341] related to the PE[342] LCA study were therefore not reviewed.

8.3.1.2 Remarks on Requirements for LCA Studies in Exemption Review Processes

Based on the current and past experiences with LCA studies in the adaptation processes of ELV and RoHS exemptions to the scientific and technical progress, the consultants would like to recommend that the Commission sets clear requirements for LCA studies used in these exemption adaptation processes. Beyond the compliance with the requirements of the ISO 14000 series, other aspects should be taken into account as well, especially:

- The life cycle scope of the LCA study:

---

336 ISO 14044-2006: Environmental management — Life cycle assessment — Requirements and guidelines

338 Ibid.

339 Teck (2014) Teck Metals Ltd. stakeholder document "Teck letter for Oeko Review of indium.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 4 June 2014 by William Booth, Antaya

340 Indium Corp. (2014a) Indium Corporation stakeholder document "Auby Analyst Visit 20092012 FINAL.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 06.06.2014, by Claire Mikolajczak, Indium Corporation

341 Indium Corp. (2014b) Indium Corporation stakeholder document "E-Mail_Indium-Corporation_LCA-Indium.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 06.06.2014, by Claire Mikolajczak, Indium Corporation

342 Op. cit. PE (2014)

The PE[343] report is a cradle to gate LCA. It does not cover the solder manufacturing phase, the application of the solder, and the end-of-life (EoL) phase.
In the consultants' opinion, LCA studies should cover all aspects of the life cycle unless there is clear and undisputed evidence that certain phases of the life cycle are irrelevant.

- Consideration of the whole product system:

  An LCA should comprise the full product system, unless there is clear and undisputed evidence that alternative approaches are comparable in a certain phase. It can be assumed that it would not affect the main results in this case, but the PE[344] report only comprises a comparison of lead vs. indium, while the product systems concern the soldering alloys, consisting of several other elements used for soldering on or in automotive glazings.

- Review of all relevant aspects of an LCA study:

  The PE[345] report provides the comparative assertions that are of highest relevance for this review process in supplement B "Indium in relation to other metals". In this supplement, the environmental impacts arising from the mining and refining of indium are compared with those from lead. Finkbeiner[346] states in his review report that supplement B was not part of his review task. Within supplement B itself, there is no information whether the LCA or other studies behind the environmental impacts of lead, silver and the other metals in the comparison have been subject to any kind of review.

- Inclusion of datasets into the review:

  Finkbeiner[347] states that the individual datasets were not part of his review. The consultants recommend that datasets should be included into the review as far as possible.

- Weighting of environmental impacts:

  ISO 14044 excludes the weighting of environmental impacts in LCA studies for public comparative assertions. In comparative studies of different product systems, e.g. two different soldering alloys, the consultants cannot decide which of the assessed product systems has an overall lower impact, as such a weighting of different environmental aspects is beyond their mandate. [348] The

---

[343] Op. cit. PE (2014)

[344] Op. cit. PE (2014)

[345] Op. cit. PE (2014)

[346] Op. cit. Finkbeiner (2014)

[347] Op. cit. Finkbeiner (2014)

[348] As example see the report of Oeko-Institut 2006, Adaptation to scientific and technical progress under directive 2002/95/EC, final report, page 13

Commission may therefore consider developing a weighting system to be applied in such public assertions.

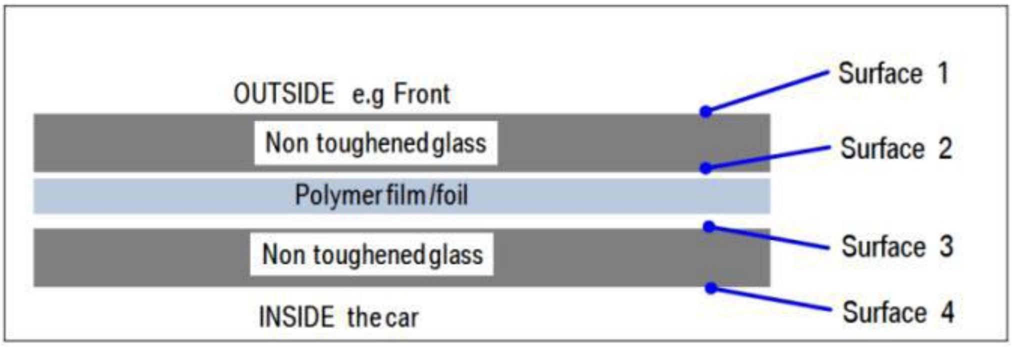
The above list of considerations is not exhaustive. It reflects aspects which have become apparent from the consultants' experience with exemption reviews in the past and at present, regarding LCA studies and environmental arguments.

8.3.2 Scope of Exemption 8(j)

8.3.2.1 Summary of the Diverging Views of ACEA et al. and Antaya

Antaya challenges the view of ACEA et al. concerning the applications, which ACEA et al. contend to be covered by Exemption 8(j). ACEA et al. interpret Exemption 8(j) to cover all applications where the lead solder is applied on non-toughened glass on surfaces 1, 2, 3 or 4, or where contacts are established in or on the polymer film or foil between the surfaces 3 and 4 of the non-toughened glass plies as indicated in Figure 8-13. From this point of view, the use of non-toughened or toughened glass is the main differentiating criterion between the scope of Exemption 8(i) and 8(j).

Figure 8-13: Structure of Laminated Glazings



Source: BMW, quoted in ACEA et al.[349]

Antaya highlights that the word "in" in Exemption 8(j), *"Lead in solders for soldering **in** laminated glazing"*, demarcates the scopes of Exemptions 8(j) and 8(i), as Exemption 8(i), *"Lead in solders in electrical glazing applications **on glass** except for soldering **in** laminated glazing",* allows the use of lead "on glass", regardless of whether this glass is toughened or non-toughened glass. From Antaya's point of view, Exemption 8(j) covers only soldering in between – not on - surfaces 2 and 3 when contacting structures embedded into the foil, while soldering on surfaces 1, 2, 3 and 4 is soldering on glass and as such covered by Exemption 8(i), not Exemption 8(j).

Antaya is, however, not consistent with this argumentation. In Table 8-2 on page 76, Antaya considers a "Printed heated device circuit on the inner surfaces of the windscreen (surface 2 or surface 3)" as an application covered by Exemption 8(j).

[349] Op. cit. ACEA et al. (2013a)

Antaya in this case considers soldering **on** surfaces 2 or 3 an application within the scope of Exemption 8(j).

8.3.2.2 Background of the Exemption Wordings

Exemptions 8(i) and 8(j) were introduced in the 2009/2010 review of Annex II of the ELV Directive.[350] Prior to that review, a joint test programme had been designed and agreed between ACEA et al. on the one hand and Antaya on the other hand, to test the performance of Antaya's lead-free solder alloy. The report of Oeko-Institut[351] lists results from these tests from page 157 on. As a matter of fact, soldering on laminated glazing (non-toughened glass) was part of the test program. Table 8-3 shows one of the test results, a comparative performance of the lead and the Antaya lead-free alloy on laminated and toughened glass.

Table 8-3: Results of Pull-off Tests by Type of Glass

Glass Type	Laminated glass		Tempered glass	
Solder	Pb-free solder	Pb-solder	Pb-free solder	Pb-solder
No. of joints	84	84	297	296
Passed	71	66	287	296
Failed	13	18	10	0
% of failures	15%	21%	3%	0%

Source: Oeko-Institut[352], page 159

The laminated glazing solder joints were applied and tested on surfaces 4 of the non-toughened glasses. No solder joints had been applied and tested on surfaces 2 or 3, or between surfaces 2 and 3 to structures in or on the polymer foil.

The background of this situation is explained in the 2009/2010 review report:[353]

> *"Soldering in laminated glazings was excluded from the Joint Test Program. Antaya had not tested its solders for this application. At a meeting of the Joint Testing Group, Antaya suggested integrating soldering in laminated glass into the testing program, but would need the glass makers' support for the supply of the laminated glass. The glass makers opposed this plan stating that soldering in laminated glass would be product and technology development and that the Joint Testing Program focuses on testing solutions which Antaya had claimed to have, not those that have to be developed. Antaya admits that none of its test results submitted to the review process proves that the lead free solution works in the "in lamination" application."*

---

[350] For details see Oeko-Institut (2010), page 151 ff

[351] Op. Cit. Oeko-Institut (2010)

[352] Op. Cit. Oeko-Institut (2010)

[353] See Oeko-Institut (2010), page 181

The wording of Exemptions 8(i) and 8(j), a result of the 2009/2010 review, reflects the above background concerning the wordings of Exemption 8(i) and 8(j). The wordings of both exemptions were discussed with all stakeholders during the 2009/2010 review, and all stakeholders besides Antaya had agreed to this wording. The wording of both exemptions was continued, unchanged, with the agreement of all stakeholders, following the 2011/2012 review.

The technical background and the details in the 2010 review report[350] as well as the wording of Exemptions 8(i) and 8(j) show that the type of glass – toughened (tempered) or non-toughened – was not a differentiating criterion for the scope of these exemptions.

Based on the conditions and results of those prior reviews, soldering to structures on or in the polymer foil between surfaces 2 or 3 are therefore in the scope of Exemption 8(j). Soldered contacts on surface 2 and 3 are contacts applied on glass, but they may also be considered as solder joints in the laminated glazing. The wording of the exemptions in the consultants' opinion allows both interpretations. In the joint test program, which was the basis for the introduction of Exemptions 8(i) and 8(j), solder joints on surface 2 or 3 were not implemented and not tested, which gives reason to include them into the scope of Exemption 8(j).[354]

8.3.3 Comments of ACEA et al. on the Presented Lead-free Soldering Applications

ACEA et al. were asked to comment the applications and claims of Sekurit. ACEA et al.[355] put Sekurit's product references in a different perspective. The Mercedes VS20, introduced into market in 2014, the new VW Passat 470 and the Golf 370 references according to ACEA et al.[356] are on or in the PVB foil, but not soldering on non-toughened glass in laminated glazing structures. The Ford CD 391 lead-free solution according to ACEA et al.[357] is not on the EU market yet, and the solution is not yet validated by Ford Europe.

ACEA et al.[358] admits that there are some technical solutions for some laminated products within the normal portfolio for the automotive glass industry, like for the contacting inside the foil, but in general and for the majority of applications lead-free solders are still subjects of intensive research and development efforts. The pilot applications show that the automotive industry works on achieving further progress and probably not only Sekurit has the knowledge. ACEA et al.[359] claims that all suppliers are active in the development of lead-free solutions, even if they are not

[354] See Oeko-Institut 2010, page 181

[355] Op. cit. ACEA et al. (2014a)

[356] Op. cit. ACEA et al. (2014a)

[357] Op. cit. ACEA et al. (2014a)

[358] Op. cit. ACEA et al. (2014a)

[359] Op. cit. ACEA et al. (2014a)

giving presentations on their developments. ACEA et al.[360] demands that this joint approach of suppliers and OEMs should be acknowledged. For connections to wire patterns in the laminate, as mentioned before, some lead-free applications are on the market even today, even though there is an unlimited exemption for that.

ACEA et al.[361] explains, however, that the experiences on some model specific pilot applications are not sufficient to derive general decisions or to resume global sourcing possibilities for all. A ramp up step-by-step is necessary. Pilot applications are always necessary to get experience for volume production and model specific pilot application results do not guarantee that a solution is feasible in every vehicle.

ACEA et al.[362] states that there are different approaches and technologies today on the market for producing laminated glass structures and electrical contacts therein, and that different companies have developed their own specific solutions. In addition, specific patent issues may have to be considered in developments. They may hinder the application of similar approaches, but on the other hand may trigger the way to new approaches.

ACEA et al.[363] states that validations in the laboratories of the OEMs and in test vehicles will show, which solutions can fulfil the demands for future vehicle models. They claim that today, there is no statement possible, if the promising Sekurit developments can solve all technical issues and in most of the vehicle models. As illustrated in the stakeholder contribution, the implementation of a solution here is a very model specific sensitive issue and a specific evaluation for each model is necessary. It is the experience of ACEA et al.[364], in their submission, that in this field the way from first promising lab-test results to the successful implementation in series cars is long and covered with failures forcing to go back to the start.

ACEA et al.[365] says they provided their statements to address Exemption 8(j) in its entirety. As it is written, Exemption 8(j) covers all laminated glass products within the automotive industry. Validated lead-free solutions are not available for all laminated products, which is also stated in Sekurit's recent communication, e.g. Sekurit excludes soldering on side 2. ACEA et al.[366] deems Sekurit's solutions suitable for "simple" in laminate soldering cases, e.g. contacting of wires and circuits within the laminate without direct contact to the glass surfaces. They can be applied in specific

[360] Op. cit. ACEA et al. (2014a)

[361] Op. cit. ACEA et al. (2014a)

[362] Op. cit. ACEA et al. (2014a)

[363] Op. cit. ACEA et al. (2014a)

[364] Op. cit. ACEA et al. (2014a)

[365] Op. cit. ACEA et al. (2014a)

[366] Op. cit. ACEA et al. (2014a)

models. There is, however, a difference if connecting structures are for antenna function or heating functions, as ACEA et al.[367] explains:

- Printed heated device circuit on surface 2, 3 (inner surfaces of the windscreen):

  St. Gobain states that soldering to surface 2 is forbidden. But, surface 2 printed products are in large volume production. Therefore, exemptions have to be maintained (existing production). There is no further information why it is forbidden, or if there is an interference with black enamel prints.

- Printed antenna device circuit on surface 4:

  If soldering to a printed circuit on surface 2 is forbidden (for technical difficulties) then soldering to a printed circuit on surface 4 has the same technical difficulties. This is especially true since in many products the inner glass (with print on surface 3 or surface 4 for example) is thinner than the outer glass. Consequently, this increases the technical difficulty for lead-free soldering.

- Printed heated circuits on surface 4:

  The lead-free application on surface 4 (non-toughened glass) is new. When Sekurit claims lead free application on surface 4 of laminated glass, it mentions it is only lab validated. Furthermore, Sekurit excludes some designs and it is thus unclear if the Sekurit solution is applicable to all existing designs or to Sekurit product portfolio only. So today, it is impossible to cover the global production.

  Connections to printed patterns on surface 3 or 4 can be necessary for certain applications, e.g. antennas, and some applications of defrosting of camera area. For these types of connection (connection to glass directly), every glass-maker complains about difficulties, only Sekurit has announced to have lab-validated solutions. ACEA et al.[368] request publication details of the solution and validation.

ACEA et al.[369] claims that lead-free soldering of non-toughened glass (incl. structures on the glass) fulfilling the specifications of the customers is not available. From Sekurit's above lead-free applications, no evidence can be resumed for what glass combinations the proposed solution can be applied (e.g. thin glass) or what surfaces are possible e.g. soldering on surface 4 and 2. There are also car specific areas, where for design or functional reasons no contact can be made; this means that the choice to design the right position for a contact is limited. ACEA et al.[370] therefore

[367] Op. cit. ACEA et al. (2014a)

[368] Op. cit. ACEA et al. (2014a)

[369] Op. cit. ACEA et al. (2014a)

[370] Op. cit. ACEA et al. (2014a)

requests that Exemption 8(j) be maintained until the entire portfolio can be successfully converted to lead-free solder.

Additionally, ACEA et al.[371] claims that the availability of glass experts is limited and several companies have to concentrate their development activities in solving the issues for toughened glass (Exemption 8(i)), which expires end of December 2015 for new type-approved vehicles.

8.3.4 Conclusions

8.3.4.1 Antaya's Lead-free Soldering Solutions

Antaya claims applications of its lead-free 65% indium alloy on surface 4 in the Ford Thunderbird (North America) and several GM U Van models for the North American and European market. These applications and the 65% indium alloy were subject to an intensive review in the 2011/2012 review[372]. The above applications were confirmed during the review. For the other applications of its lead-free alloy, described in Section 8.2.4.2 on page 92, Antaya did not disclose the car models and vehicle manufacturers, so that these applications cannot be reviewed and commented.

In the 2011/2012 review, the consultants concluded that the 65% indium alloy from the technical point of view is not an optimum substitute mainly due to its low melting point, but that it can be used at least in specific applications. Antaya claims that its other lead-free alloy, the B6 alloy, has a higher melting point, but the application examples Antaya provided in Section 8.2.4.2 on page 92 do not contain any examples for the application of this alloy. The evaluation of all arguments raised during the 2009/2010 and the 2011/2012 review are still valid in the consultants' point of view, even though the evaluation at that time was for Exemption 8(i). The consultants therefore see no reason to re-evaluate Antaya's lead-free alloys.

8.3.4.2 Lead-free Solutions Provided by Saint-Gobain Sekurit and Others

Sekurit has lead-free solutions ready for the market or at least lab tested[373] for soldering on surfaces (2), 3 and 4, and in between surfaces 2 and 3 to structures on or in the polymer foil. The lead-free solutions are based on the development of a lead-free solder and new or adaptations of existing connector designs for lead-free soldering requirements, and more specifically for soldering on and in laminated glazings.

ACEA et al. confirm that all suppliers are active in the development of lead-free solutions, even if they do not provide presentations on their developments. For connections to wire patterns in the laminate, as mentioned before, some lead-free applications are on the market even today, despite the availability of an unlimited exemption allowing the continued use of lead in such applications.

---

[371] Op. cit. ACEA et al. (2014a)

[372] For details see Oeko-Institut 2012

[373] For details see Appendix A.3.0.

The above statement of ACEA et al. is an indication that besides the solutions presented by Antaya and Sekurit, more solutions for applications covered by Exemption 8(j) are probably available on the market.

8.3.4.3 Consequences for the Continuation of Exemption 8(j)

Based on the available information, the consultants conclude that lead-free solutions for soldering applications covered by Exemption 8(j) are available in different development stages. ACEA et al. confirm that for contacts to wire patterns in the polymer foil between surfaces 2 and 3 lead-free applications are even on the market already. The unlimited continuation of Exemption 8(j) is therefore not justified.

The consultants are aware that lead-free solutions need to be adapted to the specific requirements of individual vehicles, and that this requires time and effort, and possibly further research and development work. Vehicle manufacturers, with support of their suppliers are, however, expected to adapt their designs as well, in order to avoid the use of substances restricted in legislation such as the ELV Directive. Article 4(1)(a) of the ELV Directive requires *“[…] vehicle manufacturers, in liaison with material and equipment manufacturers, to limit the use of hazardous substances in vehicles and to reduce them as far as possible from the conception of the vehicle onwards […]”, among others to make sure “[…] that materials and components of vehicles put on the market after 1 July 2003 do not contain lead, mercury, cadmium or hexavalent chromium […]”* as stipulated in Article 4(2)(a).

Exemptions can therefore not be continued until 1:1 drop-in solutions are available for all the various designs on the market. The consultants are aware that vehicle designs are the result of more than one requirement, but ACEA et al. are expected to move towards new lead-free solders and connector designs as far as possible.

ACEA et al. confirm that *“all suppliers are active in the development of lead-free solutions, even if they are not giving presentations on their developments.”* These suppliers and their customers, the vehicle manufacturers, are, however, part of the ACEA et al. worldwide consortium consisting of vehicle manufacturers and their suppliers. Even more, ACEA et al. confirm that for connections to wire patterns in the laminate, as mentioned before, some lead-free applications are on the market even today. The question arises why ACEA et al. then did not inform the consultants in detail about the status of these lead-free solutions but instead ask for the continuation of Exemption 8(j) in its current broad scope and without an expiry date.

Applicants requesting the continuation of exemptions are obliged to prove that the exemption is still required and justifiable in accordance with Art. 4(2)(b)(ii). The only detailed information received was from suppliers outside the ACEA et al. consortium. Neither the vehicle manufacturers nor their suppliers in the consortium contributed detailed information about their lead-free programs, despite requesting the continuation of Exemption 8(j) without scope limitation and without an expiry date.

Based on this situation, the consultants conclude that there is no evidence proving that the unlimited continuation of Exemption 8(j) as requested by ACEA et al. is justified by Art. 4(2)(b)(ii). The Antaya and Sekurit lead-free soldering programs show that lead-free solutions can be achieved already, and ACEA et al. confirmed that other suppliers are working on lead-free solutions as well, and that lead-free solutions are even on the market already.

It is thus recommended to introduce an expiry date for Exemption 8(j) at the end of 2019 for new type-approved vehicles. ACEA et al.[374] request 36 to 60 months-time, once solutions are available. Antaya's claim that generally only 90 days would be required for the transition to lead-free soldering was refuted in the past reviews of Exemption 8(i). The more than 60 months until the expiry of the exemption leaves sufficient time to adapt and implement lead-free solutions to the individual vehicle manufacturers' needs. In case no solutions can be found for specific applications, or more time is required in specific cases, there would still be sufficient time until the end of 2019 to apply for a specific exemption in due time, prior to the recommended expiry of Exemption 8(j).

ACEA et al. claim that the availability of glass experts is limited and that they are busy with the implementation of lead-free soldering on applications on toughened glass related to Exemption 8(i), which expires at the end of 2015. ACEA et al. did not provide further information substantiating this claim of limited capacities to a degree that would justify the unlimited continuation of Exemption 8(j) in line with Art. 4(2)(b)(ii).

8.4 Recommendation

Based on the information submitted, the use of lead in applications covered by Exemption 8(j) is no longer unavoidable, and the unlimited continuation of Exemption 8(j) is no longer justified in line with Art. 4(2)(b)(ii). Lead-free solutions are on the market already, or are in a status that allows their implementation, even though they may have to be adapted for the individual vehicles and technologies on the one hand, or they may require vehicle design and technology adaptations on the other hand. A transition period until the end of 2019 is therefore justified in the consultants' opinion. In case specific applications require the continued use of lead after 2019, the transition period until the end of 2019 is long enough to apply for specific exemptions in due time. ACEA et al. would, however, have to prove that the use of lead is still unavoidable in these cases in spite of efforts to adapt the design to the requirements of lead-free soldering, and that the continuation of the exemption is hence justified beyond 2019 for such specific applications.

The consultants recommend the following wording and expiry date for the exemption:

Materials and components	Scope and expiry date of the exemption
Lead in solders for soldering in laminated glazing	*Vehicles type approved before 1 January 2020 and spare parts for these vehicles*

[374] Op. cit. ACEA et al. (2013a)

8.5 References Exemption 8(j)

ACEA et al. 2013a	ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8j_comprehensive_answers_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/acea_clepa_jama_kama_contribution_Ex_8j_comprehensive_answers_20131104.pdf; last accessed 10.01.2014
ACEA et al. 2013b	ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_8j_further_Input_Public_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/acea_clepa_jama_kama_contribution_Ex_8j_further_Input_Public_20131104.pdf; last accessed 10.01.2014
ACEA et al. 2014a	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, JAMA, KAMA Answers_Questionnaire-2_Exe-8j_20140404-rev.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 24.04.2014
ACEA et al. 2014b	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, JAMA, KAMA Answers_Questionnaire_3_Exe-8j_20140507.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 08.05.2014
ACEA et al. 2014c	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, JAMA, KAMA Comments on ANTAYA statement on Exe-8(j)_20140507.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 08.05.2014
ACEA et al. 2014d	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA Lighthouse Applications.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 15.05.2014
Antaya 2013a	Antaya Technologies Corporation stakeholder document "20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf; last accessed 10.01.2014
Antaya 2013b	Antaya Technologies Corporation document "20131101q_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Questionaire.pdf", retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101q_Antaya_Tech_Co

	rp_Ex_8j_Stakeholder_Contribution_Questionaire.pdfhttp://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131101c_Antaya_Tech_Corp_Ex_8j_Stakeholder_Contribution_Cover_Letter.doc.pdf; last accessed 10.01.2014
Antaya 2014a	Antaya Technologies Corporation document "Antaya Response to Questionnaire-2 Exe 8j.pdf", sent via e-mail by William Booth, Antaya Technologies Corporation, to Otmar Deubzer, Fraunhofer IZM, on 14.02.2014
Antaya 2014b	Antaya Technologies Corporation document "Antaya_Response_Meeting-2014-05-09.pdf", sent via e-mail by William Booth, Antaya Technologies Corporation, to Otmar Deubzer, Fraunhofer IZM, on 19.05.2014
Antaya 2014c	Antaya Technologies Corporation document „Antaya_E-Mail_LCA-Indium_Teck.pdf", sent via e-mail by William Booth, Antaya Technologies Corporation, to Otmar Deubzer, Fraunhofer IZM, on 04.06.2014
ELV Directive	Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0053:20130611:EN:PDF; last accessed 05.12.2013
Finkbeiner 2014	Finkbeiner, M. (TU Berlin); Critical Review of the Study "Life Cycle Assessment of Indium Production", commissioned by ACEA (European Automobile Manufacturers Association), stakeholder document "ISO report indium production 2012-05-22_Summary+CR.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 25.04.2014, by Peter Kunze, ACEA
Indium Corp. 2014a	Indium Corporation stakeholder document "Auby Analyst Visit 20092012 FINAL.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 06.06.2014, by Claire Mikolajczak, Indium Corporation
Indium Corp. 2014b	Indium Corporation stakeholder document "E-Mail_Indium-Corporation_LCA-Indium.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 06.06.2014, by Claire Mikolajczak, Indium Corporation
ISO 2006	The International Organization for Standardization (2006), ISO 14044-2006: Environmental management — Life Cycle Assessment — Requirements and Guidelines, published 2006, reviewed 2010.
Oeko-Institut 2012	Deubzer, O. (Fraunhofer IZM); Zangl, S. (Oeko-Institut); Adaptation to Scientific and Technical Progress under Directive 2000/53/EC (ELV Directive) - Review of exemption 8 (i), Final Report, Freiburg, 10.03.2012; retrieved from

	http://elv.exemptions.oeko.info/fileadmin/user_upload/Exe_8_i_2011/ELV_Exemption_8i_final_report_March_2012.pdf; last accessed 10.01.2014
Oeko-Institut 2010	Zangl, S.; Hendel, M.; Blepp, M.; Liu, R. Gensch, C. (Oeko-Institut); Deubzer, O. (Fraunhofer Institute for Reliability and Microintegration IZM); Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28.07.2010, retrievable rom https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 24.01.2014
Oeko-Institut 2008	Zangl, S. (Oeko-Institut e.V.); Deubzer, O. (Fraunhofer IZM); Adaptation to Scientific and Technical Progress of Annex II Directive 2000/53/EC, final report from January 2008, Oeko-Institut e. V., Fraunhofer IZM; download from http://circa.europa.eu/Public/irc/env/elv/library?l=/stakeholder_consultation/evaluation_procedure/reports/final_report/report_revision/_EN_1.0_&a=d;
PE 2014	PE International stakeholder document “Indium Production - Life Cycle Assessment of the Indium Production Process”, commissioned by ACEA (European Automobile Manufacturers Association), stakeholder document “ISO report indium production 2012-05-22”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 25.04.2014, by Peter Kunze, ACEA
Sekurit 2013a	Sekurit stakeholder document “20131029c_Sekurit-Sekurit_contribution_ELV_Ex-8j_Coverletter_FINAL.pdf”, submitted during the online consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131029c_Sekurit-Sekurit_contribution_ELV_Ex-8j_Coverletter_FINAL.pdf; last accessed 10.01.2014
Sekurit 2013b	Sekurit document “20131029s_Sekurit-Sekurit_contribution_ELV_Ex-8j_-Statement_FINAL.pdf”, submitted during the online consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_8_j_/20131029s_Sekurit-Sekurit_contribution_ELV_Ex-8j_-Statement_FINAL.pdf; last accessed 10.01.2014
Sekurit 2014a	Saint- Gobain Sekurit document “2014-02-03_Questionnaire-2_Exe-8j_St –Gobain.pdf”, sent via e-mail by Volker Offermann, Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 03.02.2014
Sekurit 2014b	Saint- Gobain Sekurit document “2014-02-06_Saint Gobain_Lead-Free Soldering on laminated glass_external.pdf”,

	sent via e-mail by Volker Offermann, Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 06.02.2014
Sekurit 2014c	Saint- Gobain Sekurit document “2014-05-23_Questionnaire-4_Meeting-Follow-up_Sekurit_final.docx”, sent via e-mail by Klaus Schmalbuch, Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 23.05.2014
Sekurit 2014d	Saint- Gobain Sekurit document “2011-10-10_Validation_LFS flat-connector.pdf”, sent via e-mail by Klaus Schmalbuch, St.-Gobain-Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 04.07.2014
Teck 2014	Teck Metals Ltd. stakeholder document “Teck letter for Oeko Review of indium.pdf”, sent via e-mail to Otmar Deubzer, Fraunhofer IZM, on 04.06.2014 by William Booth, Antaya

9.0 Exemption 10(d) “Lead in the Dielectric Ceramic Materials of Capacitors Compensating the Temperature-Related Deviations of Sensors in Ultrasonic Sonar Systems”

Abbreviations and Definitions

OEM	Original equipment manufacturer
USS	Ultrasonic sonar systems.

Declaration

The phrasings and wordings of stakeholders’ explanations and arguments were taken over from the documents provided by the applicant and other stakeholders as far as possible. They were altered in cases where it was necessary to maintain the readability and comprehensibility of the text.

9.1 Description of Requested Exemption

The automotive and automotive supplier associations ACEA, CLEPA, JAMA and KAMA request the continuation of Exemption 10(d) in Annex II of Directive 2000/53/EC, which was due for review in 2014. The current wording of the exemption is

> *“Lead in the dielectric ceramic materials of capacitors compensating the temperature-related deviations of sensors in ultrasonic sonar systems*
>
> *This exemption shall be reviewed in 2014”*[375]

ACEA et al.[376] request the extension of the exemption for vehicles type-approved before 1 January 2019, and for spare parts for these vehicles.

---

[375] Directive 2000/53/EC (ELV) of the European Parliament and of the Council, Annex II, consolidated version from 11.06.2013

[376] ACEA et al. (2013b) ACEA, CLEPA, JAMA, KAMA stakeholder document “acea_clepa_jama_kama _contribution_Ex_10d_20131104.pdf”, submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_10_d_/acea_clepa_jama_kama_contribution_Ex_10d_20131104.pdf ; last accessed 11.11.2013

9.1.1 History of the Exemption

The exemption request[377] resulting in Exemption 10(d) was reviewed in 2009. It was found that the use of lead is still unavoidable, but that lead-free alternatives are under development.[378] The Commission followed the consultants' recommendation to grant an exemption with a review scheduled for 2014.

9.1.2 Technical Description of the Exemption

ACEA et al.[379] explain that the output precision of ultra-sonic sensors (USS) used for the back sonar of vehicles is influenced by the capacitance of the sensor. With a capacitance temperature coefficient of +0.5% per degree Celsius, the sensor's capacitance is temperature-sensitive, and the temperature-dependent change of capacitance must be compensated with a compensation capacitor. Otherwise, the correct measurement of distances across a wide temperature range is impossible. The compensation capacitor's capacitance is temperature-dependent as well, but reverse to that of the sensor. The sensor and the compensation capacitor together achieve a high accuracy of measurement within a wide temperature range. Figure 9-1 illustrates the situation.

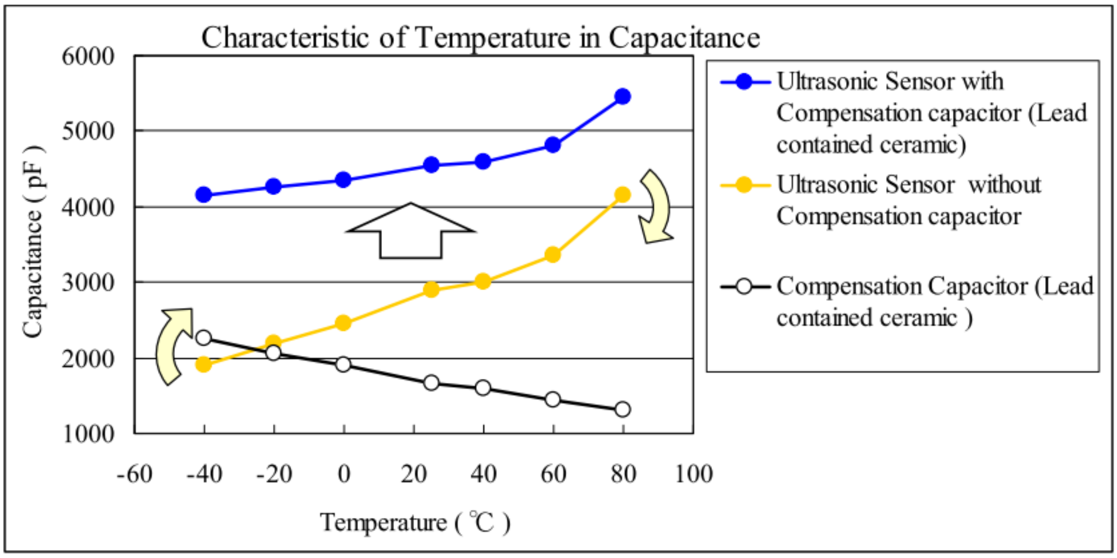
---

[377] Oeko-Institut (2010); Zangl, S., Blepp, M., Deubzer, O., Gensch, C., Hendel, M., Liu, R., Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28.7.2010, Oeko-Institut e.V. in cooperation with Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM), retrievable rom https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; accessed 05.09.2013, page 201 to 203

[378] Op. cit. Oeko-Institut (2010), page 212 to 215

[379] Op. cit. ACEA et al. (2013b)

Figure 9-1: Temperature Characteristics of the Capacitance in USS Sensors



Source: ACEA et al.[380]

ACEA et al.[381] state that the compensation capacitors that have been used so far contain lead in a dielectric ceramic. These capacitors have a large negative capacitance temperature coefficient of more than - 0.4% per degree Celsius resulting in a remaining temperature coefficient of less than 0.1% per degree Celsius for the system consisting of the sensor and the compensation capacitor.

According to ACEA et al.[382], capacitors with lead-free ceramics have a capacitance temperature coefficient between +0.3% and +0.1% per degree Celsius and can therefore not compensate the sensor's change of capacitance with the temperature. Even a difference of only 0.1% per degree Celsius is insufficient to achieve stable measurement accuracy in cars in a wide temperature range.

Further details of the technical background of this exemption can be found in the Oeko-Institut[383] report.

9.1.3 Amount of Lead Used under the Requested Exemption

The stakeholders of the 2009 review had indicated the total amount of lead used in ultrasonic sonar systems (USS) to be 45 mg, of which a maximum of 0.5 to 3 mg are

---

380 Ibid.

381 Ibid.

382 Ibid.

383 Op. cit. Oeko-Institut (2010), page 214, table 24

associated with the use of lead in the dielectric ceramic material of the compensating capacitor.[384]

In this regard, in the current review round, the stakeholders have provided the values presented in Table 9-1 below.

ACEA et al.[385] explain that the number of vehicles registered in EU 27 in the year 2012 was used as a basis for quantity calculations, corresponding to 12,053,904 passenger cars (M1) and 1,377,283 light commercial vehicles (N1), resulting in around 13.4 million vehicles.

Table 9-1: Mass of Lead (Pb) in Capacitors Compensating the Temperature-related Deviations of Sensors in Ultrasonic Sonar Systems

A	B	C	D	E	F	G
Number per vehicle	mass of ceramics per piece[1]	Mass of Pb[2]	mass of Pb per vehicle[3] (A*C)	average ratio[4]	average mass of Pb per vehicle (D*E)	overall mass of Pb per vehicles on the market in 2012[5]
(pieces)	(mg)	(mg)	(mg)	(%)	(mg)	(ton)
2	**150**	**18**	**36**	**20%**	**7.2**	**0.096**

1: mass of ceramic containing Pb
2: pure Pb (metal) content
3: category M1 and N1 vehicles in the scope of the ELV Directive
4: number of vehicles using this type of component
5: 13.4 mio.: 12.053.904 passenger cars (M1) and 1,377,283(N1) registered in the EU27 in 2012, according to ACEA

Source: ACEA et al.[386]

Based on the above calculation, the total amount of lead used under this exemption is around 100 kg per year in EU27.

---

[384] Op. cit. Oeko-Institut (2010), page 214, table 24

[385] ACEA et al. (2013a) ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013

[386] Op. cit. ACEA et al. (2013a), ACEA et al. (2013b)

9.2 Applicants' Justification for the Continuation of the Exemption

ACEA et al.[387] state that lead-free ceramic capacitors so far could not achieve a sufficiently negative temperature coefficient of capacitance to compensate the sensors' temperature sensitivity of capacitance in USS. The use of compensation capacitors with lead in the dielectric ceramics is still necessary.

9.2.1 Substitution and Elimination of Lead

ACEA et al.[388] announce that since the last review in 2009, the "Japan Auto Parts Industries Association" (JAPIA) and capacitor manufacturers have developed a technology, which can reach the required measurement performance without the use of lead, exempted in Exemption 10(d). As the next step, the reliability of such USS will have to be evaluated.

9.2.2 Roadmap to Substitution or Elimination of Lead

ACEA et al.[389] estimate that 48 to 60 months from now on are needed to test the USS with lead-free temperature compensating capacitors. ACEA et al.[390] illustrate the various steps to be taken and the timing as illustrated in Figure 9-2 below.

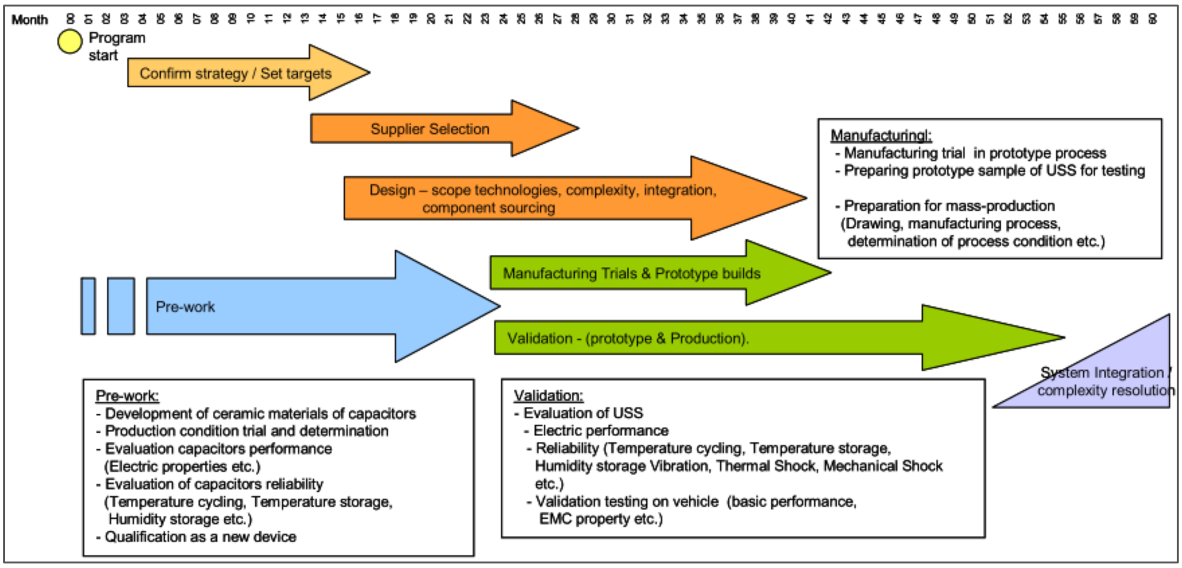
[387] Op. cit. ACEA et al. (2013b)

[388] Op. cit. ACEA et al. (2013b)

[389] Op. cit. ACEA et al. (2013b)

[390] ACEA et al. (2013c) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA-et-al_Answers_Questionnaire-1_Exe-10d_20131206.pdf", received via e-mail by Otmar Deubzer, Fraunhofer IZM, from Peter Kunze, ACEA, on 06.12.2013

Figure 9-2: Roadmap for the Substitution of Lead Contained in Temperature Compensating Capacitors



Source: ACEA et al.[391]

ACEA et al.[392] list the various steps and their anticipated timing:

- Once suitable alternatives have been identified and approved, electronic component manufactures will conduct process optimisation and qualification. They will then need to transition to the new alternative materials, before capacitors become widely available. (1-2 years)
- Capacitors will then need to be qualified at the module level before they can be installed in automotive safety applications. In the case of USS, preparation for prototype and evaluation of electric performance and reliability will be done by tier 1 suppliers, and validation testing on vehicle (basic performance and EMC property etc.) will then be conducted by the OEM. (2-3 years)
- A total transition period of 4-5 years will be required, considering the necessary period for mass-production preparation (around 1 year at the end of the validation period) and timing of vehicle model change.

ACEA et al.[393] request the continuation of Exemption 10(d) until end of 2019 with the following wording:

---

391 Ibid.

392 Ibid.

393 Op. cit. ACEA et al. (2013b)

"Lead in the dielectric ceramic materials of capacitors compensating the temperature-related deviations of sensors in ultrasonic sonar systems"

in:

"Vehicles type approved before 1 January 2019 and spare parts for these vehicles"

9.3 Critical Review

9.3.1 Substitution and Elimination of Lead

ACEA et al. argue that four to five years of time are still required to test the reliability of USS based on lead-free temperature compensating capacitors. Four to five year's time from now on would result in an expiry date for Exemption 10(d) at the earliest in November 2017, and at the latest in November 2018.

An alternative technology for USS is, however, available that does not depend on the use of a temperature compensating capacitor and lead in the dielectric ceramics of such capacitors.

There are two different ways to achieve USS not depending on the use of lead in temperature compensating capacitors:

a) Substitution of lead using a lead-free temperature compensation capacitor

b) Elimination of lead using a temperature compensating electronic circuit as an alternative technology.

ACEA et al.[394] concede that, although they had described that lead-free temperature compensating capacitors are still under development, some kinds of USS which do not depend on Exemption 10(d) have been used in actual vehicles in 2013. These types of USS are not based on lead-free temperature compensating capacitors, but on a newly designed electrical temperature compensation circuit. This method may lead to decreases in the usage volume of lead contained temperature compensating capacitors. However, according to ACEA et al., this can be applied only in the case of vehicle model changes.

9.3.2 Availability and Applicability of Solutions not Depending on Exemption 10(d)

ACEA et al.[395] claim that both the substitution and the elimination technology are available as single components, so that design change and validation testing on the

---

[394] Op. cit. ACEA et al. (2013c)

[395] ACEA et al. (2014a) ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA, KAMA Answers_Questionnaire-2_Exe-10d_20140117.pdf", sent to Otmar Deubzer, Fraunhofer IZM, via e-mail by Peter Kunze, ACEA, on 17.01.2014

USS and vehicle are required. According to ACEA et al.[396], the elimination technology is not compatible with the technology using temperature compensation capacitors. Therefore, it requires large scale design changes. As a result, the elimination technology requires further validation testing so as to ensure the safety and reliability of the vehicle. In addition, ACEA et al. claim that renewal cycles of car electronics are different between companies.

Comparing the status of the lead-free technology using a lead-free temperature compensating capacitor and the electronic compensation circuit, it is apparent that the latter must be much more advanced. While ACEA et al. claim that the substitution technology using a compensation capacitor is still under development, USS which do not depend on Exemption 10(d) eliminating the use of lead have already been applied to actual vehicles in 2013.

ACEA et al.[397] confirm that the roadmap[398] explaining the various steps to be taken and the 48 to 60 months of time required, only refers to the substitution of lead. ACEA et al.[399] at the same time claim, however, that USS using electronic circuits instead of compensating capacitors have been applied to vehicles in 2013, but cannot be applied to different vehicles without design change and validation testing (USS and vehicle). Various steps need to be taken in the vehicle development process, and ACEA et al.[400] say that as a total lead time, 48 to 60 months will be required.

Though the OEMs put forward that they need another four to five years before the new technology can be applied, the elimination technology must have been available for testing and validation in vehicles for several years before 2013 already, as it was already applied in vehicles in 2013. ACEA et al. did not provide an explanation as to why only few vehicle manufacturers tested the alternative technology in their vehicles. In the consultants' view, the claim of ACEA et al. that renewal cycles of car electronics are different between companies is not valid in this context. Most exemptions refer to new type approved vehicles only, which go through their own design process allowing for application of the new technology. The ELV Directive obliges vehicle manufacturers to apply ELV-compliant technologies at least in new type-approved vehicles once they are available, rather than allowing the continuation of exemptions to the convenience of vehicle manufacturers. The ELV Directive, its obligations, and the review and expiry deadlines of exemptions, apply equally to all vehicle manufacturers.

---

396 Ibid.

397 Ibid.

398 See section 9.2.2 on page 93

399 Ibid.

400 Ibid.

Thus, in the consultants view, the argument of ACEA et al.[401] that the use of the elimination technology in vehicles requires another 48 to 60 months like the substitution technology is not plausible. As the elimination technology has already been applied in vehicles as early as 2013, all OEMs are expected to have been able to start with testing and validation of this technology in their vehicles already. ACEA et al. however, did not indicate any obstacles that would have prevented the OEMs to test and use these USS before 2013 in their vehicles.

Overall, ACEA et al. did not provide plausible and transparent arguments as to why the elimination technology can only be applied after another 48 to 60 months lead time, despite the fact that alternative USS not depending on Exemption 10(d) are already in use in vehicles.

The exemption was discussed at a stakeholder meeting held on 9 May 2014 at Fraunhofer IZM in Berlin. ACEA et al. were asked to provide any information that had not yet been submitted, but might justify the continuation of the exemption until 2019. ACEA et al.[402] submitted the following table underpinning again the need for a total development time of 48 to 60 months (as originally indicated in Section 9.2.2 above).

Table 9-2: Steps and lead times for development to mass-production of USS[403]

	Type A: PCB design change type <actual case>		Type B: Lead-free capacitors compensating the temperature-related deviations type <prediction>	
Electronic component supplier	Manufacturing testing sample and Evaluation of capacitor performance (changing of constant trans)	3 months	Evaluation of capacitor performance	3 months
	Evaluation of capacitor reliability	2 months	Evaluation of capacitor reliability	9 months
	Preparation for mass-production (Trans)	2 months		
Automotive Tier1	Approval for new component (Trans)	2 months	Approval for new component (Capacitor)	6 months
	Evaluation of EMC property (Newly designed PCB)	6 months		
	Manufacturing for testing sample (USS assy)	3 months	Manufacturing for testing sample (USS assy)	3 months
	Evaluation of electrical performance (USS assy)	6 months	Evaluation of electrical performance (USS assy)	3 months
	Evaluation of reliability (USS assy)	9 months	Evaluation of reliability (USS assy)	9 months
	Preparation for mass-production (USS assy)	6 months	Preparation for mass-production (USS assy)	6 months
Automotive OEM	Approval for USS assy	3 months	Approval for USS assy	3 months
	Validation testing on vehicle (basic performance, EMC property etc.)	12 months	Validation testing on vehicle (basic performance, EMC property etc.)	12 months
		Total 4.5 years		Total 4.5 years

401 Ibid.

402 ACEA et.al. (2014b), ACEA, CLEPA, JAMA, KAMA stakeholder document "General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 28.05.2014

403 Ibid.

The above table does not add substantial information to the already available data. The consultants did not question the total time required for the development and implementation of ELV-compliant USS. The crucial point is that the development time for the elimination solution, the temperature compensating circuit USS, must have started before 2013 or 2014 to enable its use in 2013 vehicles. Furthermore, based on the information submitted vehicle manufacturers could have tested and used this new technology already.

9.3.3 Assessment of the Expiry Date

ACEA et al. claim a development time of 4.5 years (44 months) for both types of ELV-compliant solutions. According to ACEA et al., the elimination solution ("design change type" in the above Table 9-2) was already in use in 2013. The development at that time must therefore have been advanced to the stage where the OEM does the validation testing of the USS in vehicles, which according to the above Table 9-2, justifies another 12 months of transition period. All the more as no information is available proving that such tests would not have been successful. The use of lead therefore has become avoidable already, and Art. 4(2)(b)(ii) does not justify the continuation of the exemption until 2019 as requested by ACEA et al.

ACEA et al. claim that the adoption of the new technology requires design changes, which require additional time. In past review rounds, this fact has been taken into account, where appropriate, with the expiry of exemptions for new type approved vehicles only so that current models do not need redesign to achieve ELV compliance.

Based on the information submitted, the consultants propose an expiry of the exemption at the end of 2016, and to continue the exemption for vehicles type-approved before this expiry date. This will, on the one hand, restrict the design adaptations to newly type-approved vehicles, and on the other hand limit the number of USS required, thus enabling, if still relevant, a smooth ramp up of USS production and, if necessary, design adaptations on the side of the USS producers for new type approved vehicles that are currently under development.

9.4 Recommendation

Based on the available information, the consultants recommend continuing Exemption 10(d) until the end of 2016 for vehicles type-approved before 2017. A new technology for ultrasonic sonar systems not depending on Exemption 10(d) is available and already in use in vehicles and can be applied to new type approved vehicles. The use of lead is therefore avoidable and the continuation of Exemption 10(d) beyond this date would not be in line with the stipulations of Art. 4(2)(b)(ii).

The consultants recommend the following wording and timing for Exemption 10(d):

Materials and components	Scope and expiry date of the exemption

Lead in the dielectric ceramic materials of capacitors compensating the temperature-related deviations of sensors in ultrasonic sonar systems	*Vehicles type-approved before 1 January 2017 and spare parts for these vehicles*

9.5 References Exemption 10(d)

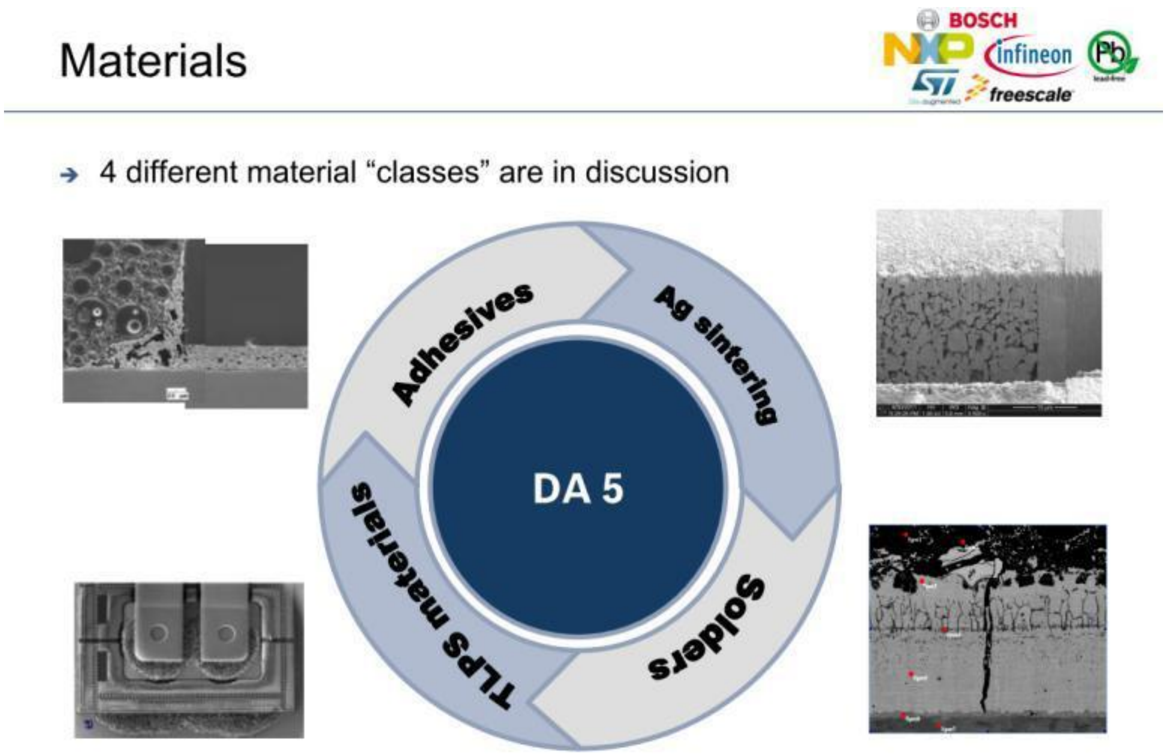
ACEA et al. 2013a	ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/acea_clepa_jama_kama_contribution_cover_letter_20131104.pdf; last accessed 11.11.2013
ACEA et al. 2013b	ACEA, CLEPA, JAMA, KAMA stakeholder document "acea_clepa_jama_kama_contribution_Ex_10d_20131104.pdf", submitted during the online stakeholder consultation, retrieved from http://elv.exemptions.oeko.info/fileadmin/user_upload/Consultation_2013_1/Exemption_10_d_/acea_clepa_jama_kama_contribution_Ex_10d_20131104.pdf; last accessed 11.11.2013
ACEA et al. 2013c	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA-et-al_Answers_Questionnaire-1_Exe-10d_20131206.pdf", received via e-mail by Otmar Deubzer, Fraunhofer IZM, from Peter Kunze, ACEA, on 06.12.2013
ACEA et al. 2014a	ACEA, CLEPA, JAMA, KAMA stakeholder document "ACEA, CLEPA, JAMA, KAMA Answers_Questionnaire-2_Exe-10d_20140117.pdf", sent to Otmar Deubzer, Fraunhofer IZM, via e-mail by Peter Kunze, ACEA, on 17.01.2014
ACEA et al. 2014b	ACEA, CLEPA, JAMA, KAMA stakeholder document "General-Answers_Follow-up-Questionnaire_ACEA-et-al_20140528.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Peter Kunze, ACEA, on 28.05.2014
ELV Directive	Directive 2000/53/EC of the European Parliament and of the Council on end-of life vehicles, retrieved from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0053:EN:NOT; last accessed 29.11.2013
Oeko-Institut 2010	Zangl, S.; Blepp, M.; Deubzer, O.; Gensch, C.; Hendel, M.; Liu, R.; Adaptation to scientific and technical progress of Annex II to Directive 2000/53/EC (ELV) and of the Annex to Directive 2002/95/EC (RoHS), revised version of the final report, Freiburg, 28.07.2010, Oeko-Institut e.V. in cooperation with Fraunhofer Institut für Zuverlässigkeit und Mikrointegration (IZM), retrievable from https://circabc.europa.eu/sd/d/a4bca0a9-b6de-401d-beff-

6d15bf423915/Corr_Final%20report_ELV_RoHS_28_07_2010.pdf; last accessed 05.09.2013

Appendices

A.1.0 Appendix 1: Information Provided by DA5 Concerning Exemption 8(e)

Source of the below information: DA5 (2014e)[404]

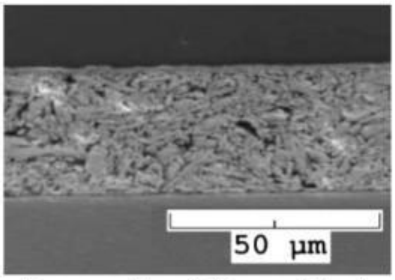


[404] DA5 2014e, DA5 (Bosch, Freescale Semiconductor, Infineon Technologies, NXP Semiconductors, STMicroelectronics) stakeholder document "DA5_customer_presentation_070514.pdf", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Bodo Eilken, Infineon, on 5 May 2014

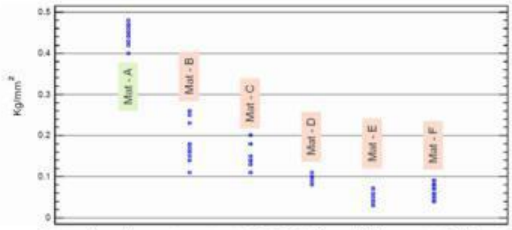
High Thermal Conductive Adhesives I

- Principle
  - Very high conductivity of adhesives is achieved with an increased silver content and very dense packing of filler particles.
  - Key factors are optimized silver particle size distribution with smaller particles and/or partial/full sintering of the silver particles during the resin cure process.
- Advantages
  - Common production methods and equipment can be used for the application of the material and placement of the chip.
  - Adhesives pass automotive environment stress test conditions.
- Limitations
  - The high filler loadings make the rheology of the materials more critical and tighter process control is required.
  - Some materials contain a solvent , where contamination of bond and leadframe surfaces is possible.
  - Different leadframe plating and die backside require a dedicated adhesive type.
  - Material cost is higher compared to standard adhesives and solder.
  - Application is restricted to low and medium power devices and packages with maximum moisture sensitivity level of MSL3/260°C.

High Thermal Conductive Adhesives II

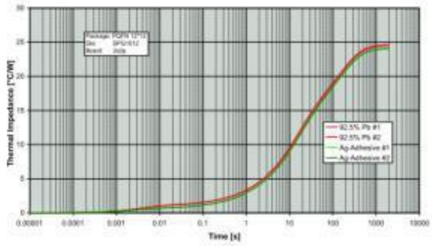


Dense packing of silver particles in the x-section of an adhesive bond line



Hot die shear test at 260°C for different Adhesives
(30mm² die on Ag plated leadframe)

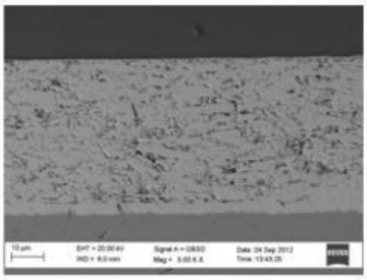
Dispense pattern with solvent bleed on the leadframe surface



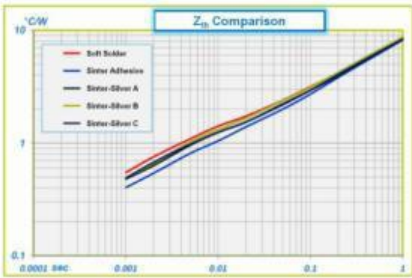
Thermal performance of the device is comparable to solder die attach

High Thermal Conductive Adhesives III

- The development of very high conductivity adhesives is heading towards a further reduction of filler particle size, thus stimulating a sintering process between the single silver particles during the resin cure process.
- The technology shall combine the advantages of an adhesive (thermal-mechanical stability, less sensitive to various surfaces) with the higher conductivity of a sintered material.
- Handling of these materials and control of manufacturing processes, however, can pose a greater challenge compared to an adhesive.



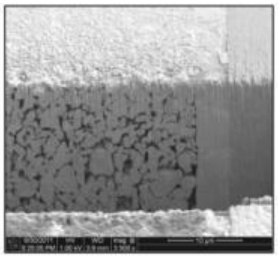
Cross- section of an Adhesive with Sintered Silver Particles



Comparison of Thermal Resistance
Sintered Adhesive vs. Soft-Solder, Sinter-Ag

Ag Sintering I – Overview

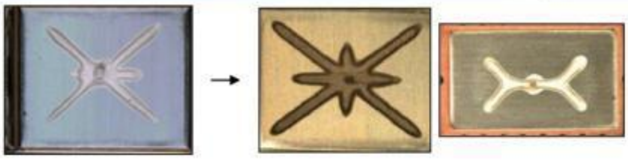
- Principle
  - Ag-sinter pastes: Ag particles (µm- and/or nm-scale) with organic coating, dispersants, & sintering promoters
  - Dispense, pick & place die, pressureless sintering in N2 or air in box oven
  - Resulting die-attach layer is a porous network of pure, sintered Ag



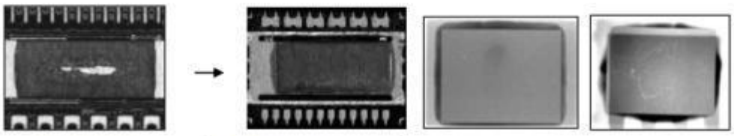
- Advantages
  - Fulfills many of the drop-in replacement requirements for a paste
  - Better thermal and electrical performance than Pb-solder possible
- Disadvantages
  - No self-alignment as with solder wetting
  - nm-scale Ag particles are at risk of being banned
  - New concept in molded packaging - no prior knowledge of feasibility, reliability or physics of failure
  - Production equipment changes might be needed (low-O_2 ovens?)
- Elevated risks
  - Potential limitations in die area/thickness, lead frame & die finishes
  - Potential reliability issues: cracking (rigidity), delamination or bond lift (organic contamination, thickness reduction due to continued sintering), interface degradation or electromigration of Ag (O_2 or humidity penetration, unsintered Ag particles in die-attach layer)

Ag Sintering II – Assembly

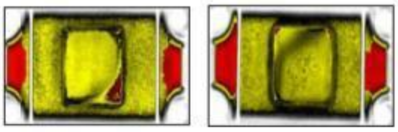
- Dispensability and staging time are improving, but issues persist



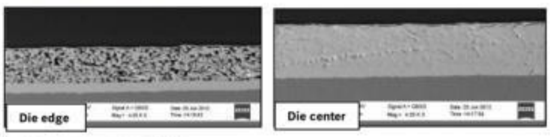
- Voiding is improving



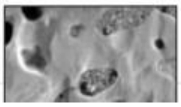
- Process control issue: C-SAM scans are difficult to interpret



- Bond line density differences and un-sintered material should be improved

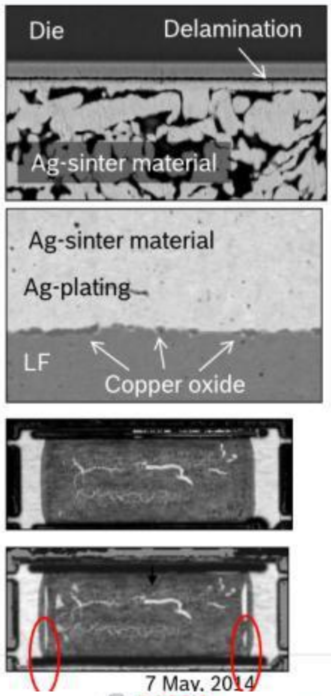


- Unsintered Ag-particles can remain after curing



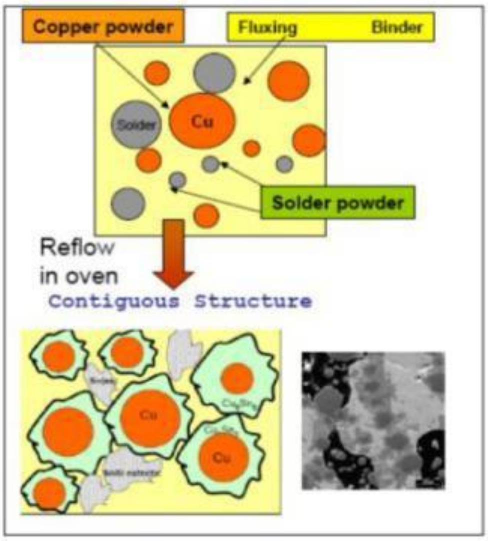
Ag Sintering III – 0-hr & Reliability Results

- Oxidation and/or delamination of interfaces is common, even at 0-hr, lowering adhesion and electrical & thermal performance. Potential solutions (not yet proven):
  - Reduce oxygen content in atmosphere during curing
  - Change paste formulation to allow for lower sintering temperature
  - Change die back-side metallization
- In cases with no delamination, high DSS (20 N/mm^2) and good thermal performance can be had with Ag finishes
  - In-package electrical performance still lags Pb-solder
- No test configuration has yet to pass all required reliability tests after MSL1 preconditioning
  - Results after MSL3 preconditioning are better, with reduced cracking and delamination
  - Recent results show further improvements, but still some delamination after temperature cycling and pressure pot / autoclave tests
- Physics of failure understanding missing/ongoing: already porosity and bond line thickness changes seen
  - Die penetration test shows non hermetic die attach (at least for ~1mm from the edges of the die)



27 7 May, 2014

TLPS Materials I

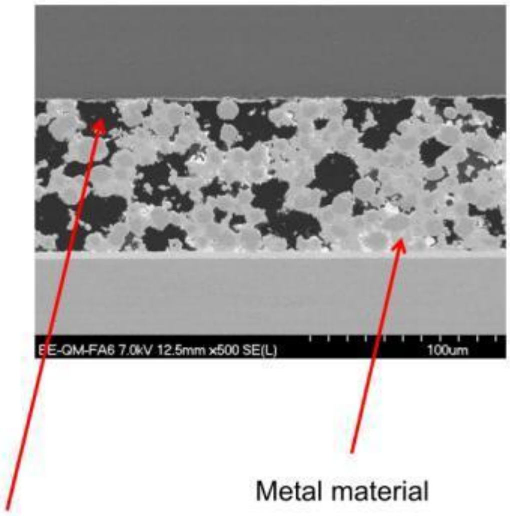


Principle

- Advantages
  - Fulfills many of the drop-in replacement requirements for a paste
  - Better cost position compared to Ag sintering solutions
- Disadvantages
  - Medium metal content in die attach
  - High space rate, filled with Epoxy
  - New concept in molded packaging - no prior knowledge of feasibility or reliability
  - Only suitable for small dies < 13mm^2
- Elevated risks
  - Potential limitations as die attach for high power devices (low electrical and thermal conductivity compared to Pb solder)
  - Potential reliability issues: spaces lead to cracks in die attach

TLPS Material II

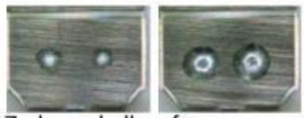
- The hybrid material showed a very high space rate. The spaces are filled with epoxy material
- The reflow process is very critical and has to be further optimized, the reflow profile seems to be product specific
- Reliability results are contradictory. Results are package dependant. A low space rate is mandatory to survive reliability
- Shear values at 260°C are low, barely above the minimum needed value (5N/mm²)



Alternative Solders I

Properties to be considered

- Robust manufacturing process
  - Repeatable solder application
  - Stable wetting angle
  - Surface compatibility (chip backside, lf finish)
- Reliability
  - Voiding / cracking / disruption after stress
  - Growth of brittle intermetallics at high temperature
  - Disruption during temperature cycling



Zn based alloy reference

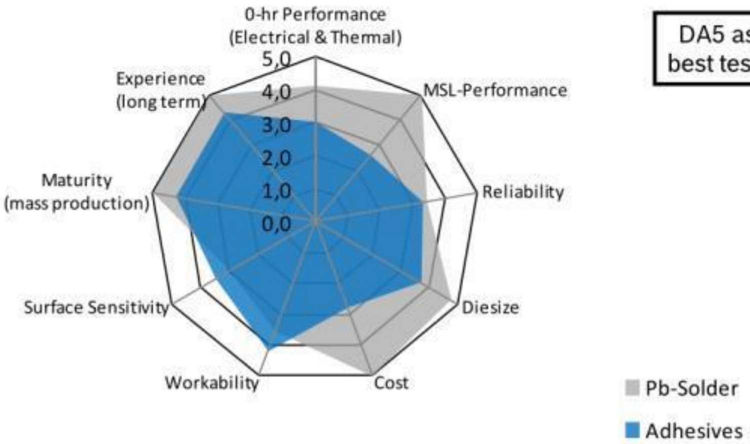
Alternative Solders II

- Zn-based Alloys
  - Improved workability demonstrated
  - New formulations demonstrate lower mechanical stress and reduced die cracking, still further improvement required
  - Limited experience on reliability
  - Risk of Zn re-deposition can only be falsified in high-volume manufacturing
  - Material currently only available in wire form
- Bi-based Alloys
  - Low thermal conductivity & low melting point
  - Performance minor to high lead solder
- SnSb-based Alloys
  - Low melting point (new formulations show possible increase)
  - Workability challenging (increased voiding)
  - Limited surface compatibility (chip backside, leadframe finish)
  - Limited experience on reliability
  - Material currently only available in paste form

Key Performance Indicators I

Comparison of competing Technologies

Adhesives vs. Pb-solder



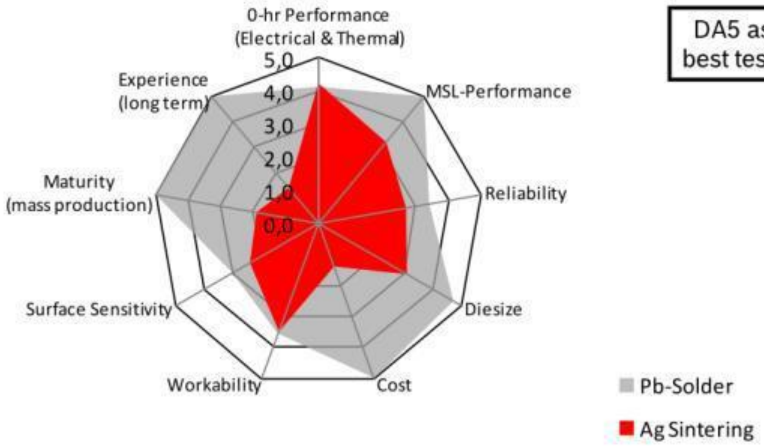
DA5 assessment refers to best tested material in class

(rating: 1 very poor, 2 poor, 3 fair, 4 good, 5 very good)

Key Performance Indicators II

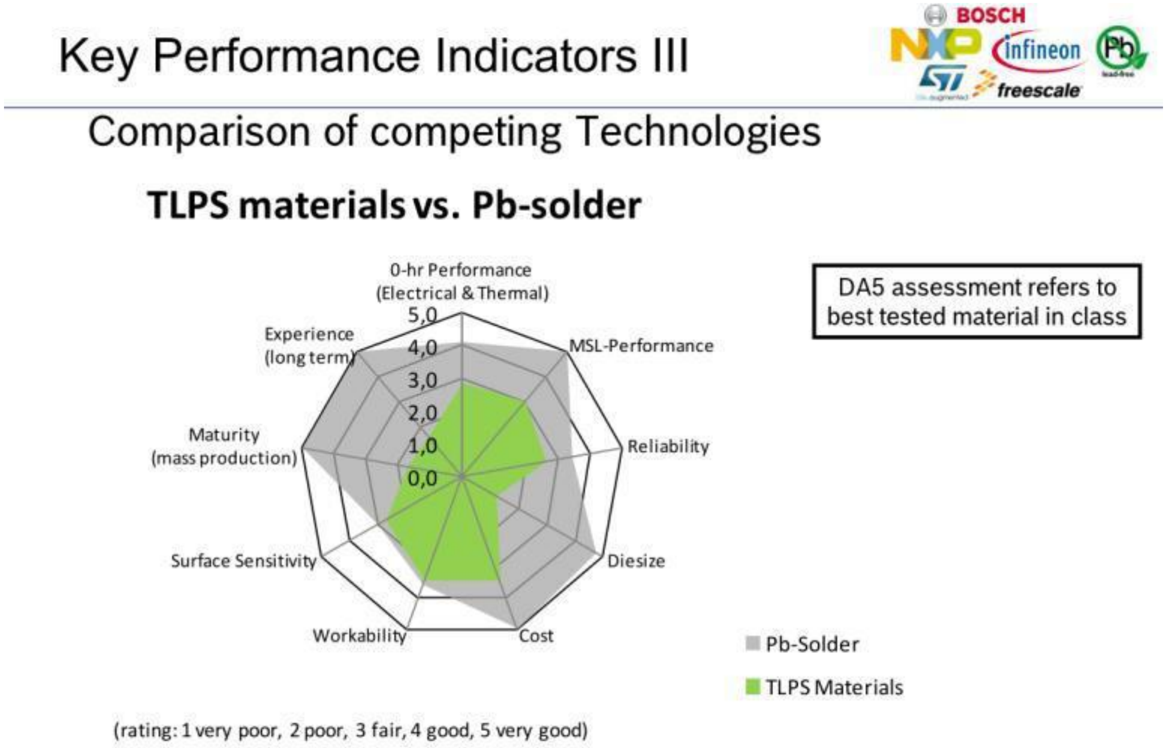
Comparison of competing Technologies

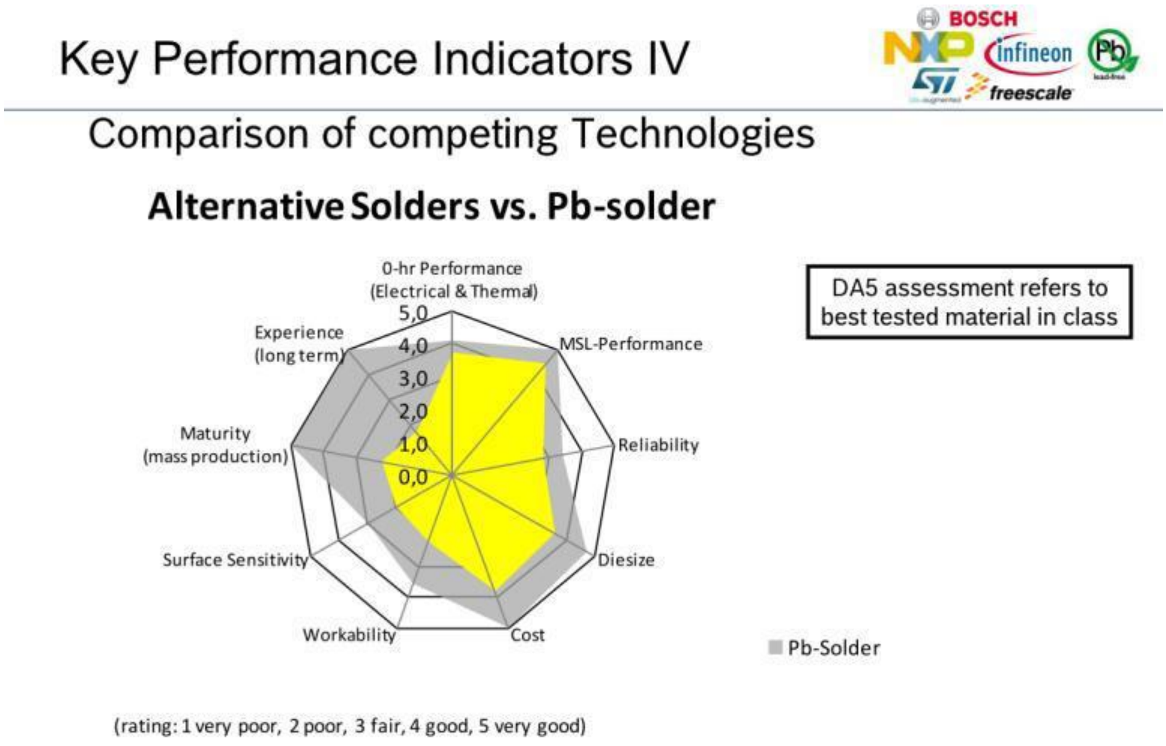
Ag Sintering vs. Pb-solder



DA5 assessment refers to best tested material in class

(rating: 1 very poor, 2 poor, 3 fair, 4 good, 5 very good)





Source of the above information: DA5 (2014e)

A.2.0 Appendix 2: Information Provided by Epson Concerning Exemption 8(e)

The below answers to the consultants' questions were provided by Epson (2014)[405].

1. Quartz crystal resonator with metal cap are in principle available with lead-free solders like they can, for example, be used in watches. They do not depend on the use of lead high melting point solder (HMPS). To which degree are such solutions viable for automotive applications as well, and what are the limits of their use in automotive applications?

   <Answer for Q1>

   Quartz crystal resonators are indeed available in metal cans not using any Pb, but this devices can withstand only lower process and storage temperatures and thus require manual soldering due to the lower heat resistance caused by the use of Pb-free low melting solder for the cylinder sealing. The wider temperature range of automotive applications as well as SMD assembly/reflow soldering however requires the use of higher solder temperatures which would cause the sealing of low melting solders to leak, so that this processes require the use of higher temperature cylinder sealings based on HMPS.

   Reflow solder processes run on higher temperatures and SMD-mounting requires the cylinder crystals commonly to be mounted on a kind of lead frame by means of a first soldering process before this combination is molded into a plastic and undergoing a final reflow process for mounting onto customers printed circuit board. Due to the fact that the cylinder sealing is exposed to multiple soldering processes including reflow soldering with higher temperatures than manual soldering, this components are thermally more stressed during assembly and thus it is necessary to increase the melting point of the cylinder capsulation (hermetic sealing of the metal cylinder with a plug) in this cases compared to the one where the cylinder is directly hand soldered onto the PCB. For these cases the use of HMPS is needed, as no other material has been found so far which combines the high melting point and the mechanical characteristics (i.e. softness and ductility) required to assure reliable hermetic sealing between the metal cylinder and the plug for long time and over wide temperature ranges in storage and operation.

   Even more, many applications can't work with a pure crystal, but need an oscillator of some type (i.e. Temperature-Compensated-Oscillators (TCXOs) for GNSS applications or real time clock modules). In these cases, the

[405] Epson Europe Electronics GmbH, stakeholder document "ELV 8e Epson.doc", sent via e-mail to Otmar Deubzer, Fraunhofer IZM, by Stefan Hartmann, Epson, on 4 July 2014

hermetically sealed crystal resonator has to be mounted together onto a kind of module with an IC. So the same basic structure and arguments about the multiple soldering processes as mentioned above are valid in this cases, as the cylinder crystal (where used) has to be mounted onto a PCB, lead-frame or similar together with the semiconductor before molding.

In other words, HMPS as sealing material is not only required for cylinder crystals to enable SMD soldering, but as well in widely spread components like RTC modules and others, where an IC and hermetically sealed quartz crystal have to be combined together inside one package/module to achieve desired specifications (like i.e. accuracy).

Additional comment:

While manual soldering was quite common many years ago, it is not compatible with modern PCB production machines and would require a manual and thus labor intense and expensive mounting process not compatible with the one used for all other components on conventional PCBs. Even though, these manual assembly processes are indeed still common in dedicated industries like in the watch industry, as modern quartz watch movements only contain 2 components. One being the IC, which is typically wire bonded and the other one being the quartz. So in this case it makes not this much of a difference if the single component which needs to be soldered is soldered using a reflow or manual soldering process. Nearly all other industries however cannot use this manual process due to process compatibility (meaning the compatibility with mounting processes for other components on the complex modules) and reliability reasons (machine soldered joints are just more reliable and vary less than manual joints).

2. Alternative surface mount devices (SMD) are available like ceramic packages with metal case (or lid) with a ceramic lid instead of a plastic moulded metal cylinder. These devices do not need hermetic sealings based on lead HMPS. In principle, these devices could therefore be an alternative to avoid the use of lead in order to achieve ELV compliance, if these devices would be used instead of the metal can types.
    a. Please explain whether and how far this is possible, or where this alternative technology cannot replace the quartz crystal resonators with metal cap and why.

<Answer for Q2-a>

Metal can crystals cannot be completely replaced by crystals packed into ceramic packages, as the characteristics and covered frequencies are vastly different. The most remarkable differences are:

- Due to the different dimensions (fitting into the packages), the smaller crystals have a significantly different “pullability”. This is the capability to change the frequency when external circuit parameters (namely the load capacitance of the oscillation circuit) are changed. This is a feature used to correct the initial tolerance and frequency drift over temperature as well as aging of the crystal and is required to meet standards for wireless and wired communication as well as GNSS applications. The high pullability of larger cylinder crystals is especially important in wide temperature applications like in automotive use, as the frequency temperature tolerance is far larger due to the wider temperature range which has to be covered which consequently needs a wider pulling range (so range in which the frequency can be changed).

- Due to the physical sizes of applicable ceramic packages, the crystals inside available ceramic packaged quartzes are smaller compared to the ones inside metal cylinders. The smaller size of the quartz crystal however increases its internal loss (so called "ESR"; electrical serial resistance), thus requires oscillator circuits which can drive significantly more current and thus require more electrical energy in operation. As many of this cylinder crystals are used for so called "clock" applications, so using a 32.768kHz crystal to derive a time signal out of it, this oscillators have to be operated all the time (so even while the application is not in use), so would impact the standby and "off" current of applications. Beside the pure power consumption concern, it is further important to mention that power consumption is for several reasons (legislations, environmental, operation time on i.e. batteries) very important for nearly all applications. For this reason, nearly all Semiconductor Manufacturers are putting technologies in place to reduce the power consumption of their ICs. As a result as well the available energy for the oscillator is going down, so that many of the latest ICs require extremely low ESR crystals which can using todays technologies only be achieved with crystals packed into a metal cylinder (due to size reasons as mentioned above).
- Since the outer dimensions of the quartz crystal define its resonance frequency, the smaller ceramic packages do not allow to generate rather low frequencies (like 4MHz, 6MHz or 8MHz), which however are often used to clock CPUs. Increasing this frequency would require different CPU chips and increase the power consumption in use unnecessarily.

b. Please also indicate in case these alternative technologies require the use of any of the substances restricted in the ELV Directive (Pb, Cd, Hg, Cr6+). If possible, a comparison of the amounts of restricted substances used in the two different technologies would be useful as well.

<Answer for Q2-b>

As explained in the answer document submitted on 4th April, ceramic packages are generally available in 2 different configurations:

Base	Lid	Sealing	Main Characteristic
Ceramic	Metal	Metal with seam welding	Limited temperature range
Ceramic	Ceramic or glass	low melting glass (using Pb)	Wide temperature range and high reliability

In order to assure the hermetic sealing of the package over a wide storage or process temperature range like required in automotive applications or when assembling the ceramic crystal onto a leadframe to form a module including other components (like ICs), it is absolutely essential to avoid mechanical stress inside the hermetically sealed package as this could cause micro-cracks and thus component malfunctions (since air might be sucked into the vacuumed hermetically sealed package through micro-cracks). Ceramic has nearly no thermal expansion, so that the use of a metal lid is very limited to applications with a relatively small storage temperature range. Automotive applications however need an extremely wide storage temperature range (depending on the application within the car from i.e. -40°C to min. 105°C up to more than 150°C). The use of a metal lid would cause significant mechanical stress between the ceramic body and the metal lid, which would cause the hermetic seal to brake and develop micro-cracks when exposed to extreme temperatures. As a result, these applications can only use glass or ceramic lids which equally have nearly no thermal expansion (like the ceramic body of the package). In order to combine the ceramic body and the lid, it is necessary to use a glass with low melting point in the joint area (as metal joint materials would again cause mechanical stress due to thermal expansion). The relatively low melting point of about 320°C for the sealing glass is needed, because the crystal inside ceramic packages is glued and the glue as well as the crystal itself is sensitive to high temperatures, which would cause increased aging (higher frequency errors) and unwanted characteristics (like frequency dips due to statistically increased probability of crystal structure defects inside the quartz crystal through increased activation energy applied by means of heat). In order to achieve this lower melting point, it is necessary to add Pb to the sealing glass. This use is exempted in ELV 10(a) and RoHS 7(c)-I.

Due to the smaller size of ceramic packages, the amount of Pb inside a ceramic package should be smaller than the one in metal can crystals, but unluckily I do not have available or access to any data quantifying this.

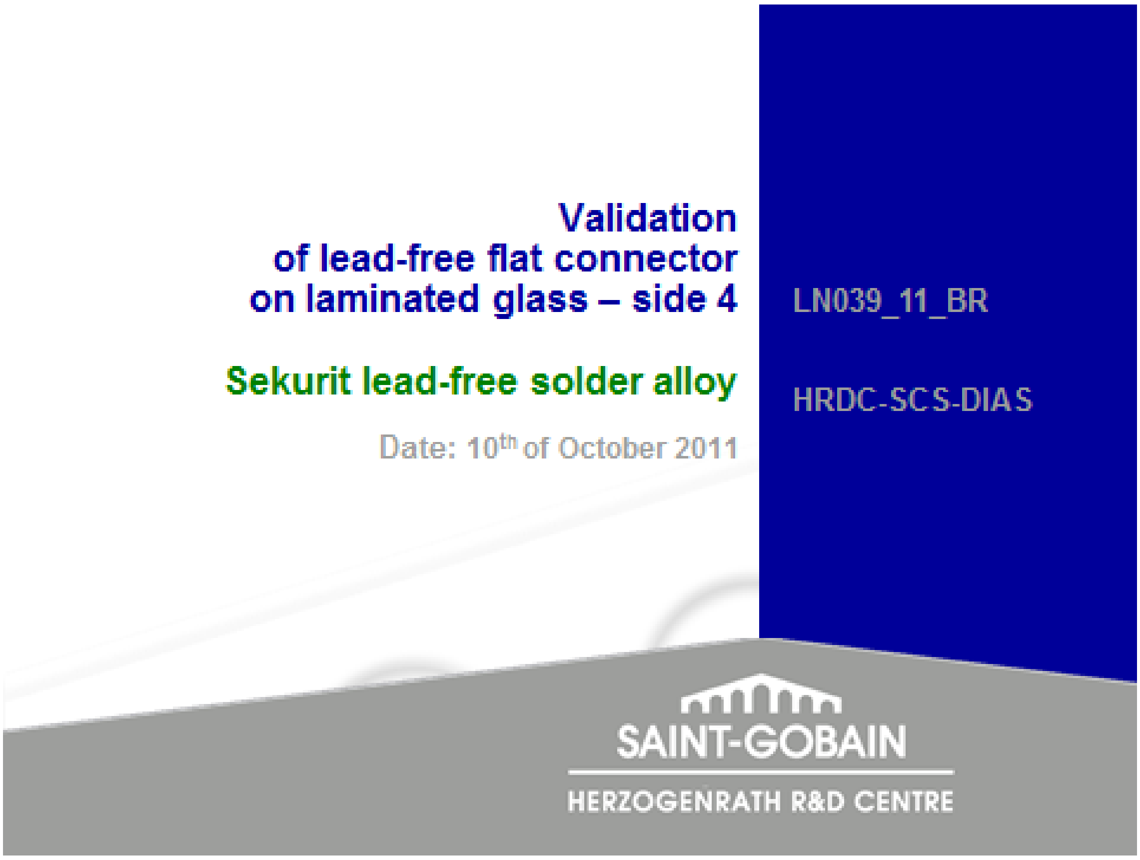
3. In case there are any other aspects which are relevant, we would like to ask you to mention them as well.

<Answer for Q3>

Historically ceramic packaged crystals have been significantly more expensive than metal can crystals, but the recent years this price gap has become rather insignificant so that they are preferably used for new designs due to the smaller size wherever the characteristics allow doing so. In other words, the industry is self-motivated to move to ceramic crystals if any possible, but unluckily a complete replacement of cylinder crystals using HMPS with ceramic packaged crystals is not possible in all cases and applications due to the limitations mentioned under 2a, so that the extension of the exemption for HMPS is absolutely needed.

A.3.0 Appendix 3: Information Submitted by Sekurit Concerning Exemption 8(j)

The following information was submitted by Sekurit (2014d)[406].



[406] Sekurit 2014d Saint- Gobain Sekurit document "2011-10-10_Validation_LFS flat-connector.pdf", sent via e-mail by Klaus Schmalbuch, St.-Gobain-Sekurit, to Otmar Deubzer, Fraunhofer IZM, on 04.07.2014

Investigation of flat connector on laminated glass – side 4

- Test design:
  - Merc W212 ws with flat connector for wiper park heater
  - Sekurit lead-free solder alloy
- SGS-standard process: Hot stamp soldering
- Durability test conditions:
  - group A: TCT -40..+105°C with 60 cycles
  - group B: HT 120°C for 500 h
- Salt spray, humidity, TCT with mechanical load and electrical current

  obsolete for flat connectors because of construction / design:
  A double sided tape seals the soldering area and protect the soldered joint against pull manipulation.

SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

2

Investigation of flat connector on laminated glass – side 4

Results

✓ Product feasibility by supplier
✓ Solderability with SGS standard process
✓ Durability High-Sn alloy

Next steps

➔ optimisation of solder depot spreading
➔ trials with antenna flat connector systems

SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

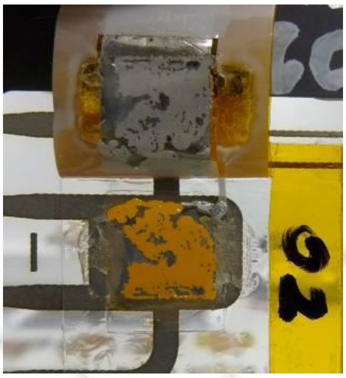
3

Investigation of flat connector on laminated glass – side 4

Reference - after soldering

Sekurit
lead-free
solder alloy

View from side 4



OK → Cohesion failure after pull-off

SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

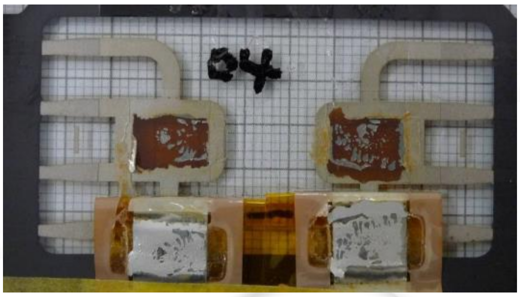
4

Investigation of flat connector on laminated glass – side 4

after TCT -40°C..+105°C; 60 cycles

Sekurit
lead-free
solder alloy

View from side 4



OK → Cohesion failure after pull-off

SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

5

Investigation of flat connector on laminated glass – side 4

after **HT 120°C for 500h**

Sekurit
lead-free
solder alloy

View from side 4

OK → Cohesion failure after pull-off

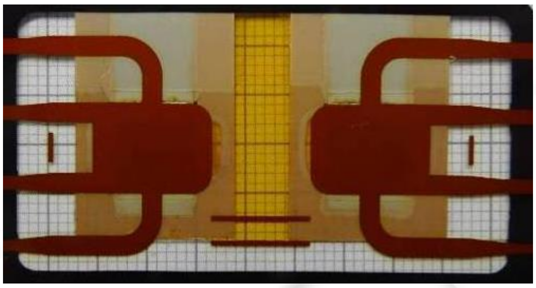
SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

Investigation of flat connector on laminated glass – side 4

after **TCT -40°C..+105°C; 60 cycles**

Sekurit
lead-free
solder alloy

View from side 3



OK → No delamination of silver

→ No glass defects

SAINT-GOBAIN
HERZOGENRATH R&D CENTRE

Investigation of flat connector on laminated glass – side 4

after TCT -40°C..+105°C; 60 cycles

Sekurit
lead-free
solder alloy

View from side 4

OK → Cohesion failure after pull-off

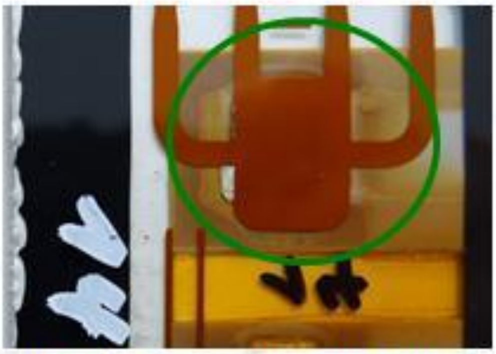
8

Investigation of flat connector on laminated glass – side 4

after HT 120°C for 500h

Sekurit
lead-free
solder alloy

View from side 3



OK → No delamination of silver

→ No glass defects

9

The source of the above information is Sekurit (2014d).