ACEA European Automobile Manufacturers Association — CLEPA European Association of Automotive Suppliers — JAMA Japan Automobile Manufacturers Association, Inc. — kama

9th Adaptation to scientific and technical progress of Exemptions 8(e), 8(f)(b), 8(g), 8(j) and 14 of Annex II to Directive 2000/53/EC (ELV), Stakeholder Consultation Questionnaire

Submission to Stakeholder Consultation concerning Annex II ELV directive Exemption No. 8(e) "Lead in high melting temperature type solders (i.e. Lead-based alloys containing 85% by weight or more Lead)"

With this application the automotive industry, represented by their associations ACEA, JAMA, KAMA, CLEPA et al. asks to extend above mentioned exemption.

In this section we take reference to the questionnaire[i] from OEKO Institute published on 29th May 2018.

We would like to express our opinion concerning stakeholder consultation on exemption no.8(e) of Annex II of Directive 2000/53/EC (ELV Directive). This exemption is still essential and needs to be continued.

Questions (Answers in blue color)

1. Please explain whether the use of lead in the application addressed under Ex. 8(e) of the ELV Directive is still unavoidable so that Art. 4 (2) (b) (ii) of the ELV Directive would justify the continuation of the exemption. Please be specific with your answer, for example clarify, if applicable, what types of vehicles your answer refers to, ie, conventional vehicles and various types of hybrid and electric vehicles, and which functionalities and applications the exemption still needs to cover.

<Answer 1>

With implementation of Lead-free soldering procedures for automotive electronic circuit boards (ECBs), the soldering process temperatures increased. The applied Lead-free solders like SAC solders have a higher melting point. As a consequence, contacts in the interior of active and passive electronic components need to resist the higher solder temperatures. This is one of the reasons why high melting temperature type solders on Lead base are applied.
We expect that the change from Lead-based soldering procedures to Lead-free soldering procedures reduced the average Lead-content per ECB by more than 95%.

Table 1 lists intended uses and related products in which HMP Leaded-solders under exemption 8(e) are utilized. The table also includes reasons why they are needed.
As explained in detail in the answer for 2nd question, Lead-free materials which can alternate wide range of applications have not been developed yet. Therefore, the use of Lead in the application addressed under exemption 8(e) is still unavoidable. This is valid for all vehicle types addressed in question 1.

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

Table 1: *Intended Use and Examples for Related Products in which HMP Lead-solders are utilized*

*) long term reliability under the harsh environmental conditions of use in vehicles needs to be assessed and qualified according to automotive specifications (e.g. AEC-Q100[2]).

2. Please explain the efforts your organisation has undertaken to find and implement the use of lead-free alternatives for automotive uses. Please refer to alternatives, which at least reduce the amount of lead applied or eliminate its necessity altogether.

<Answer 2>

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 three intended uses (Table 1), an alternative technology with similar ductility, strength and further physical properties as Lead is not yet available.

Lead-free solders of metallic systems that have a solidus line temperature of 250°C or higher, as well as electrically conductive adhesive systems, have problems and thus cannot substitute Lead HMP solders. In addition, as a trend of vehicle components, further miniaturization of structures proceeds, and brings increase of thermal and mechanical load on components.

Especially components requiring long term reliability (e.g. powertrain system components, high power applications such as generator diode etc.) and safety relevant components (Brake ECU, Steering ECU etc.) will be largely affected.

For electrified vehicles extended operating times apply as here driving, stand by and charging of accumulator need support of electronic control systems. (typically, up to around 8.000 hours driving) due to new operational modes like charging (typically up to around 30.000 hours), pre-conditioning (typically up to around 3.000 hours) or on-grid parking (future).

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

Table 2 lists types, melting temperatures and applicability judgement of Lead-free solders that are currently (as of June 2018) in use and of which commercial viability is currently under study.
Peak soldering temperature profiles of Lead-free soldering processes are higher than the melting temperature (up to around 250 or 260°C) to enable wetting and reliable contacts.

Category	Solder Type	Alloy Composition [wt %]	Melting Temperatures (Solidus Line / Liquidus Line)	Applicability judgement
Lead-free solders (Solidus Line 250°C or lower)	Sn-Zn(-Bi)	Sn-8.0Zn-3.0Bi	190~197 °C	Poor
	Sn-Bi	Sn-58Bi	139 °C	Poor
	Sn-Ag-Bi-In	Sn-3.5Ag-0.5Bi-8.0In	196~206 °C	Poor
	Sn-Ag-Cu-Bi	Sn96Ag2.5Bi1Cu0.5	213~218 °C	Poor
	Sn-Ag-Cu	Sn-3.0Ag-0.5Cu	217~220 °C	Poor
		Sn-3.5Ag-0.7Cu	217~218 °C	Poor
		Sn-4Ag-0.5Cu	217~229 °C	Poor
	Sn-Cu	Sn-0.7Cu	227 °C	Not good
	Sn-low Sb	Sn-5.0Sb	235~240 °C	Not good
Lead-free solders (Solidus Line more than 250°C)	Bi system	Bi-2.5Ag	263 °C	Not good
	Au-Sn system	Au-20Sn	280 °C	Not good
	Sn-high Sb	Sn->43Sb	325~>420 °C	Not good
	Zn-Al system	Zn-(4-6)Al(Ga,Ge,Mg)	About 350~380 °C	Poor
	Sn system & high melting temperature type metal	Sn＋(Cu,Ni,etc.)	≧about 230~ >400 °C	Not good

Table 2: *Composition and Melting Temperatures of Main Lead-free Solders*

Figure 1 shows the relationship of types and melting temperatures of Lead-containing solder and Lead-free solders, based on the data shown on Table 2.

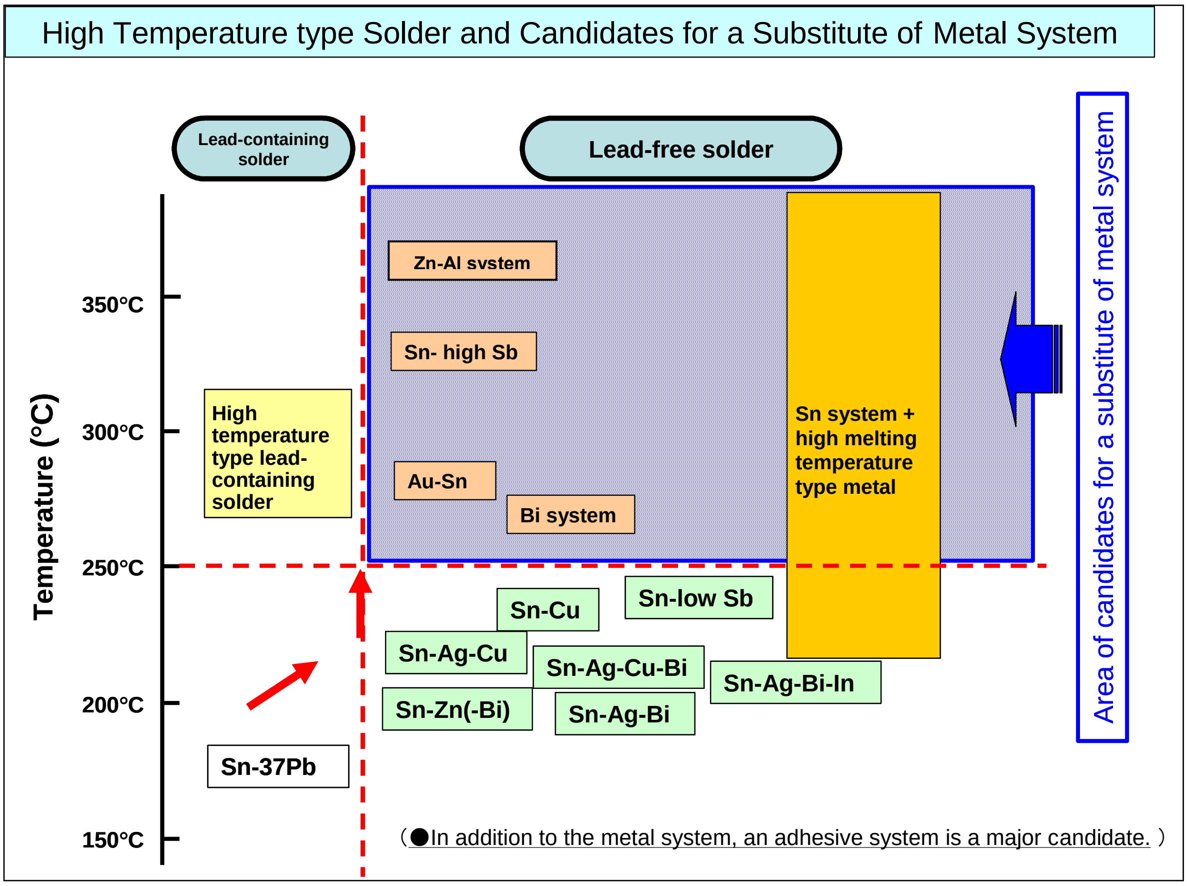


Fig. 1: *Relationship Diagram of Solders and Melting Temperature*

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

In the following, Table 2 shows advantages and disadvantages of Lead-free solders with a solidus line temperature of 250°C or higher and electrically conductive adhesives that are candidates for the replacement of high temperature type Lead-containing solders as listed in Fig.1.

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

Table 3: *advantages and disadvantages of High Temperature Lead-free Solders and conductive adhesive systems*

As shown on Table 3, both Lead-free solders of metallic systems that have solidus line temperature of 250°C or higher and electrically conductive adhesive systems have problems and thus cannot substitute high-temperature type Lead-containing solders.

For R&D activities and test results we make reference to the DA5 consortium submission, which will be provided as a separate submission. The DA5 project report gives the scientific based justification for extending exemption 8(e).

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

<Answer 3>

Figure 2 shows a roadmap for the substitution of HMP leaded solders.

Automobile industry already required development of alternative material to suppliers of electronic parts and semiconductor parts and provided them with specification of development by B to B base and have continuously observed their R&D activities. However, as explained in the 2nd section, currently no alternative Lead-free technology can be predicted for the future.

Even if:

- development of
- assessment of and
- replacement with alternative products progress,

widespread use of high temperature type Lead-containing solders in all related application requires time for appropriate qualification for automotive uses based on the long-term reliability requirements. Based on this large amount of variables a further extension and future review date is highly requested by the authors of this answer.

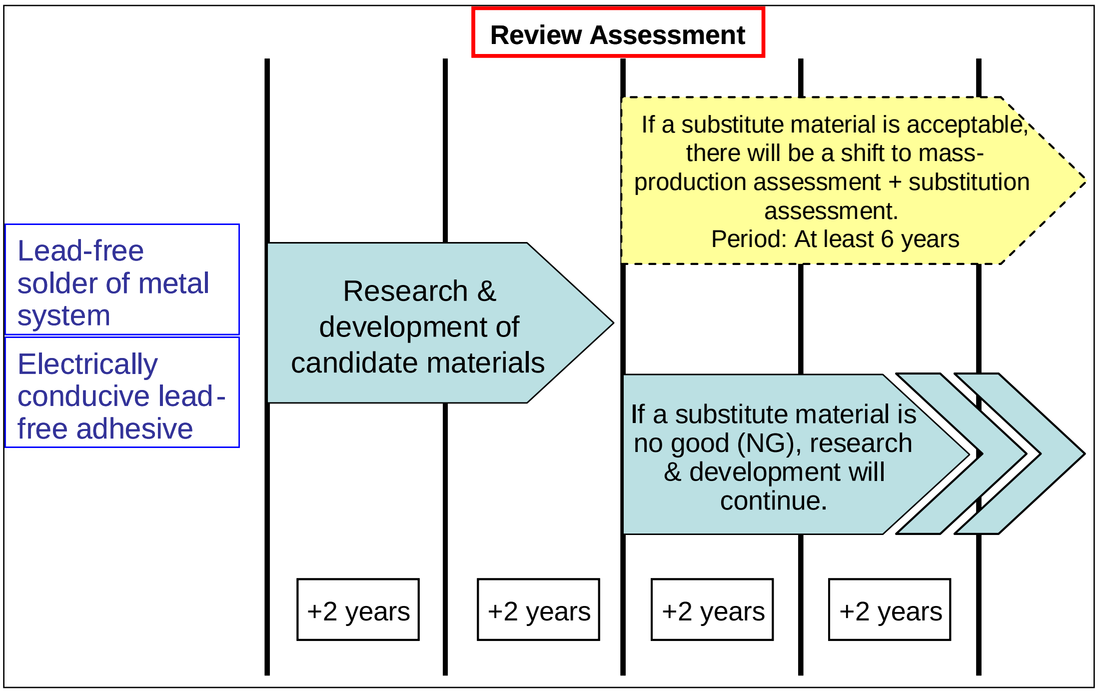


Fig. 2: *Roadmap*

4. What is the amount of lead that would be contained in LHMTS in vehicles
   a) placed on the EU market
   b) worldwide

   in case the exemption is continued? Please provide a substantiated estimate clarifying how you have arrived at the stated result.

<Answer 4>

We estimated the amount of Lead that would be contained in LHMTS in vehicles by two approaches on how to estimate amount of Lead used under exemption 8(e) per vehicle as follows.

Approaches:

1) Calculation based on investigation result on amount of ECB per vehicle and amount of Lead used under exemption 8(e) per ECB
2) Anonymized investigation to OEMs in associations

Estimation results:

1) We used the following figures for calculation.
   - Average volume range of ECBs per vehicle: 1.5 to 3.0kg/vehicle (source: ACEA)
   - Amount of Lead used under exemption 8(e) per ECB: 0.01 to 0.05% (source: ZVEI)

   By multiplying the above figures, amount of Lead used under exemption 8(e) per vehicle would be **0.14 to 1.4g / vehicle** as follows.

   Minimum: 1.5kg of ECB x 0.01% of Lead x 90% of Lead = 0.14 g / vehicle
   Maximum: 3.0kg of ECB x 0.05% of Lead x 90% of Lead = 1.4 g / vehicle

Conservatively estimated we assume an average weight of 2.5kg ECBs per vehicle which would result in a range between 0.24 and 1.24g/vehicle.

2) In general, depending on amount of ECB in a vehicle, use figures for Lead used under exemption 8(e) are scattering in a range **between 0.4 and 1.5 g / vehicle**. This result is in line with 1).

   Based on the above results, we assumed **1g/vehicle** for average volume calculation of Lead used by exemption 8(e).

Assuming that in the EU28 market 15.65 million vehicles are new registered in 2017 (ref: OICA statistics 2017), the total amount of Lead would be below 15.65 million x 1g = 15.65 tons of Lead in LHMTS solder per year.

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

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

In general, we agree with the necessity to continue the exemption 8(e).
As stated above, currently no alternative Lead-free technology can be predicted for the future. The investigated potential alternative materials currently available have some drawbacks on reflow temperature and component design etc. that make them not suitable for all automotive application. Therefore, automobile industry request continuation of the current exemption.

Date: 24th July 2018

Annex (page 1/3)

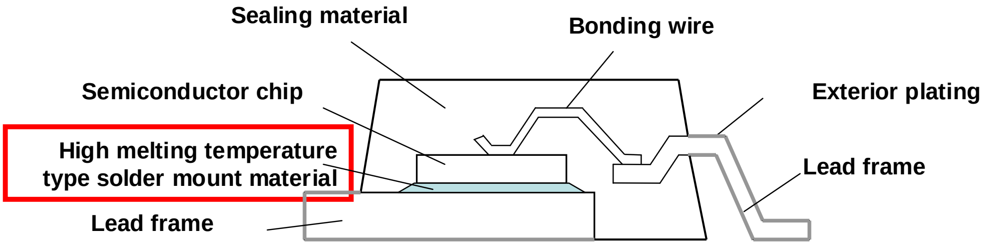


Fig. 1 Schematic Cross Sectional View of Power Semiconductor

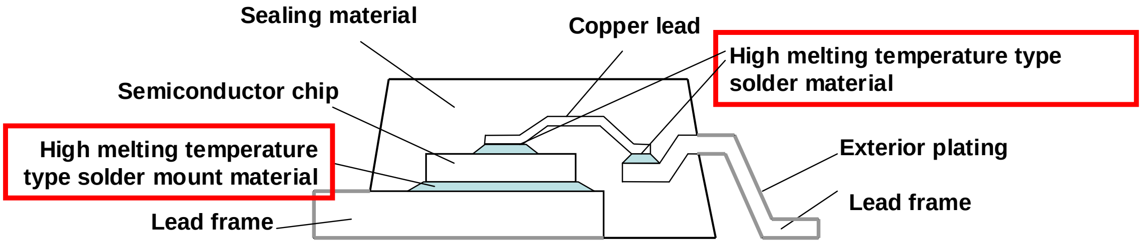
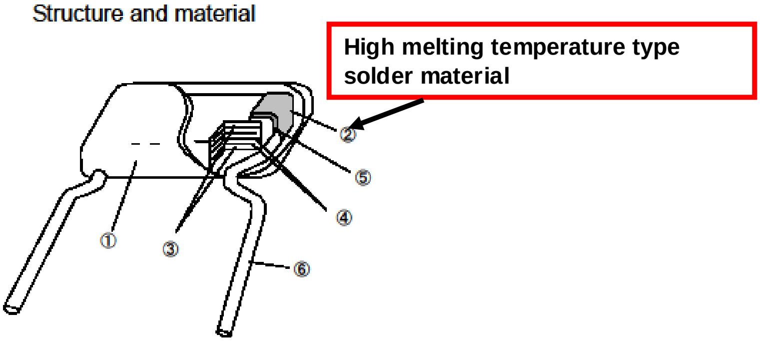


Fig. 2 Schematic Cross Sectional View of Internal Connection of Semiconductor

Annex (page 2/3)

Structure and material

1. Structure



2. Material and Description

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

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

Fig. 3 Schematic View of Capacitor with Lead

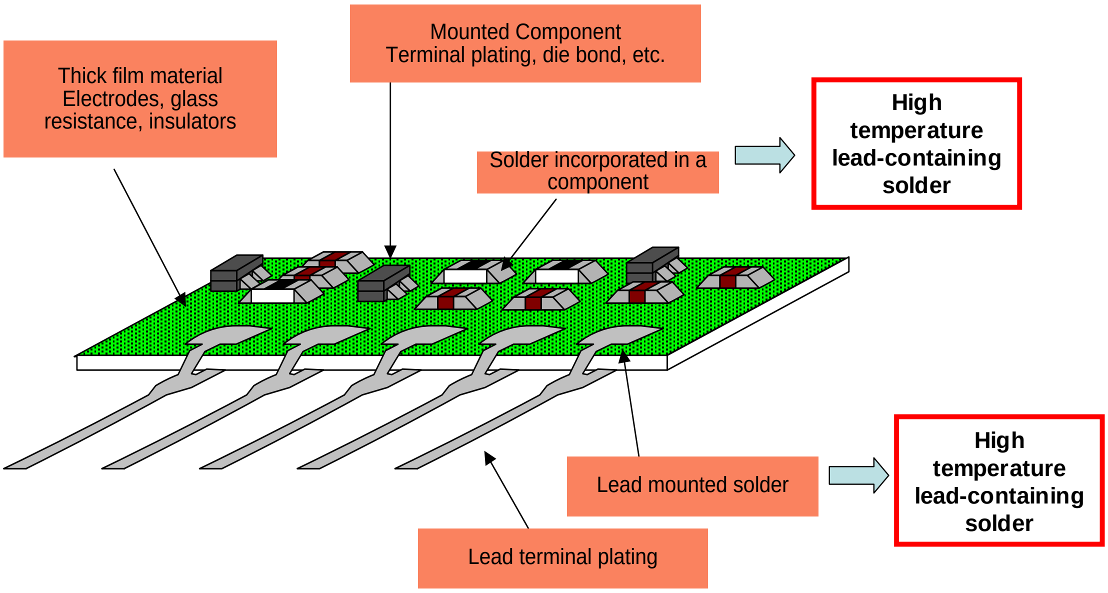


Fig. 4 Schematic View of Circuit Module Component

Annex (page 3/3)

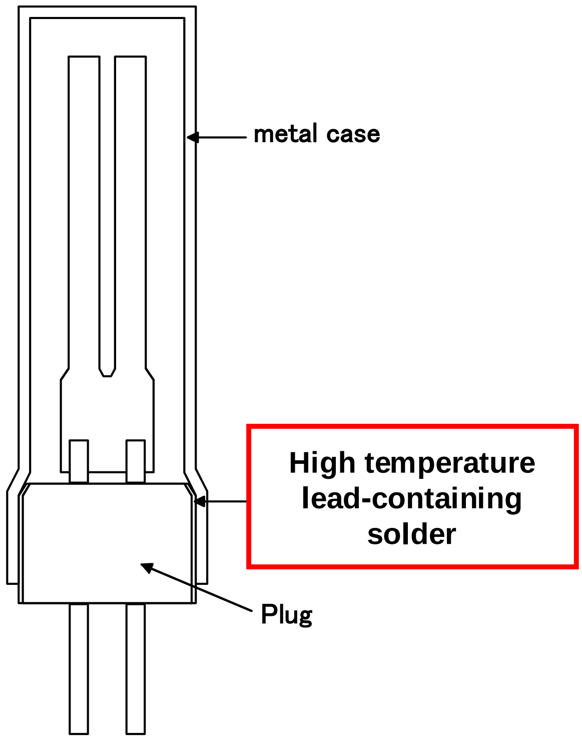


Fig.5 Schematic View of Crystal Resonator

[i] http://elv.exemptions.oeko.info/index.php?id=64