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)

Consultation Questionnaire Exemption No. 8(e)

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

Input of the automotive industry expert group, represented by ACEA, JAMA, KAMA, CLEPA, et al.
Base of the contribution has been provided by JAPIA, JEITA[1], JEMA[2], CIAJ[3], and JBMIA[4] and completed by other associations.

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1 Japan Electronics and Information Technology Industries Association
2 The Japan Electronic Manufacturers' Association
3 Communications and Information Network Association of Japan
4 Japan Business Machine and Information System Industries Association

We would like to express our opinion concerning consultation on exemption No. 8(e) of Annex II of Directive 2000/53/EC (ELV Directive) to effect that the exemption should be continued and substitution would be difficult resp. not possible today.

The above mentioned industry stakeholders request continuation of the exemption.

Note: The DA5 (Die Attach 5) consortium[5] is expressing their opinion concerning semiconductor packages (one specific application covered under 8(e)) specifically and separately but in line and in addition with these comments. DA5 technical comments about feasibility of lead-free technology and outlook for alternation are consistent with these comments, which refer to the whole applications and related products in which lead (high melting point) HMP solders under the exemption are used. (ref: Die Attach 5 - Stakeholder Consultation Answers Version 1.7, 11-October-2013)

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5 Consortium to jointly investigate and standardize the acceptance of alternatives for high-lead solder for attaching die to semiconductor packages during manufacturing. This Consortium is formed by Bosch (Division Automotive Electronics), Freescale Semiconductor, Infineon Technologies, NXP Semiconductors and STMicroelectronics.

Questions & Answers

1. *Please indicate whether there are any other applications where HMP lead-solders are used.*

Table 1 lists typical types and melting temperatures of solders currently (as of August 2013) used in applications falling under this exemption. For your reference, it also lists types and melting temperatures of solders containing 85% or less lead, use of which is prohibited under ELV Directive.

Category	**Solder Type**	**Alloy Composition [wt %]**	**Melting Temperatures (Solidus Line / Liquidus Line)**
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

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

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

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)	

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

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

Questions & Answers

The following applications are typical examples for uses of lead HMP solders as described in the previous review in 2009/2010.

1. Internal electrical interconnections in components
2. Die attach
3. Plastic overmoulding
4. Ceramic BGAs
5. High power applications
6. Hermetic sealings

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 2.

2. In 2009, the investigation and development of a few possible alternatives to the use of HMP solders was already underway, but it was not possible to identify applicable alternatives at the time. Please describe:
a) in which applications the use of lead-containing HMP solders has become avoidable
b) the tests or other works that have been performed to this extent, and explain the results with respect to the applications of lead HMP solders.

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 2), an alternative technology with similar ductility and strength as lead is not yet available.

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, and brings increase of thermal and mechanical load on components. Especially components requiring long term reliability (e.g. powertrain system components, high power applications such as generator diode etc.) and safety relevant components (Brake ECU, Steering ECU etc.) will be largely affected. In addition, after production technology has been changed, very careful scrutiny is needed to maintain required high quality of components in the process to avoid failure in actual field.

Table 3 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 under study.

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

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

Figure 6 shows the relationship of types and melting temperatures of lead-containing solder and lead-free solders, based on the data shown in Table 1 and 3.

Questions & Answers

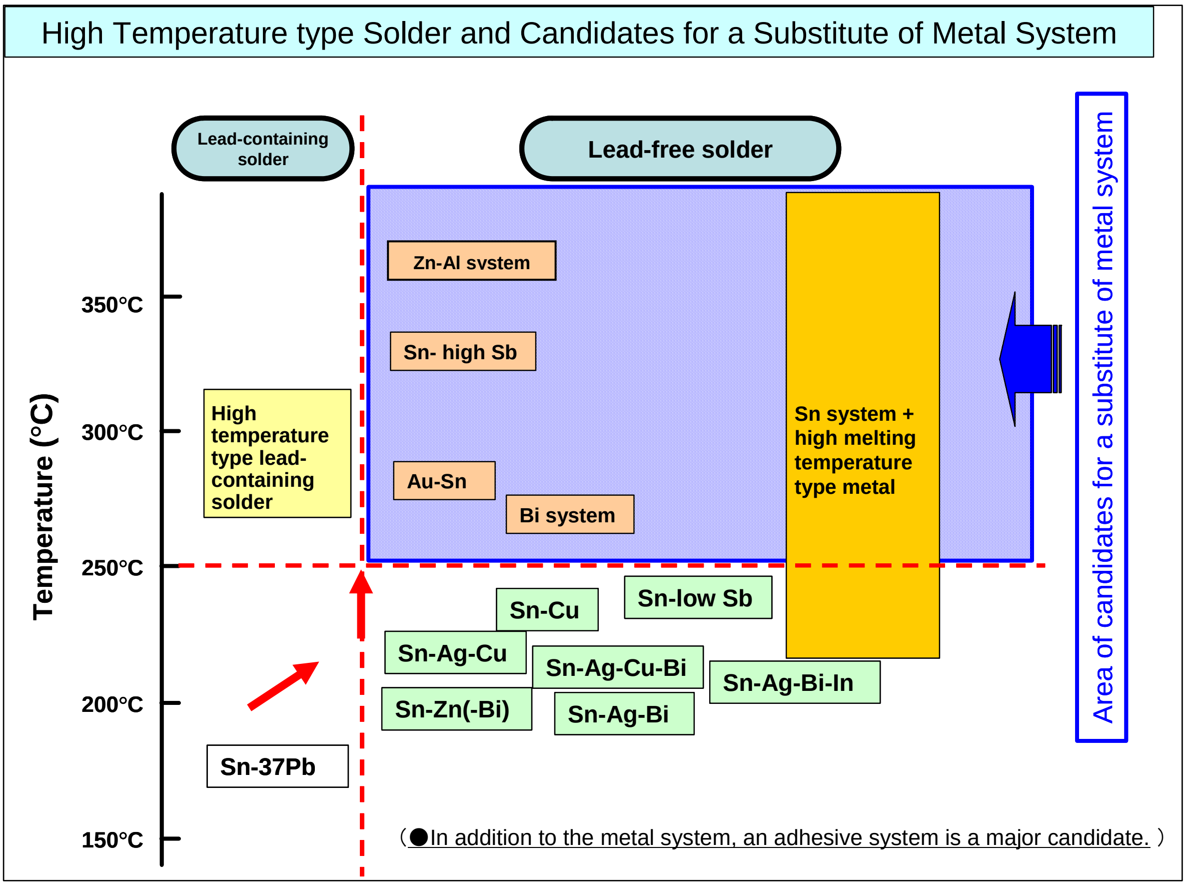


Fig. 6: *Relationship Diagram of Solders and Melting Temperature*

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 4 shows advantages and disadvantages of lead-free solders and electrically conductive adhesives with a solidus line temperature of 250 °C or higher 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 4: *Advantages and Disadvantages of High Temperature Lead-free Solders*

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

As an example for R&D activities related to exemption 8e we refer to the DA5 consortium submission to this stakeholder consultation (cf. page 1). This report gives scientific based evidence for the need of high melting point lead containing solder in related automotive applications.

3. For hermetic sealings, Swatch had applied for an exemption under the RoHS Directive for the use of lead used in hermetic sealings in quartz crystal resonators. The exemption request was assessed and recommended not to be granted, as lead-free solutions were available. The consultants therefore assume that at least in this application, the use of lead is avoidable. Please explain:

a) whether and how far you agree with this conclusion. If you do not agree, please provide evidence that lead-free solutions offered, for example in Annex III in the report of Öko-Institut (2006), are not viable for hermetic sealings used in automotive applications.

The mentioned application for an exemption from Swatch was for a low melting point lead solder with 37% lead alloy[1]. So indeed there are lead free alternatives for low melting point

[1] See Oeko final RoHS report from 2006 p.83 6.22 „Use of up to 37% of lead in solder alloys .. in quartz movements"

lead solders and in the mean time this substitutions are widely used.
However, we understand that there was no discussion about the substitution of lead HMP solders, therefore, we do not agree with the comment that lead-free solutions were available in HMP solders at that time. Manufactures have been taking efforts to develop lead-free technology for HMP solders, but up to now nobody has found any lead-free materials which reach the required performance and reliability, and therefore we conclude that there is no solution available to substitute lead HMP solders at this point in time.

b) in which other hermetic sealings are lead HMP solders used, and whether and how far the above lead-free solution is transferable to these applications.

Lead HMP solders are used in SAW（Surface Acoustic Wave）filter, crystal oscillators and crystal filters etc. for hermetic sealings other than in quartz crystal resonators. However, feasibility of lead-free technology and its technological hurdles in these applications are similar to the quartz crystal resonators.

c) whether there are any other solutions for hermetic sealings making the use of lead avoidable, if not yet explained under question 2.

All the solutions are included in the answer under question 2, so please refer to that.

Questions & Answers

4. Please indicate how much lead would be used under those applications in which the use of leaded HMP solders is unavoidable. Please substantiate the amount of lead with a calculation for vehicles put on the European market, and worldwide.

The majority of high powered components are found in steering, braking and powertrain electronic control units (ECU). Nearly all automotive electronic products contain components utilizing high lead solder. Assuming that the amount of lead used in solder in the above applications is ~ 0.003g per electronic component, then typical automotive ECU's would contain:

Application	**Components per ECU (approx)**	**Pb solder [g/vehicle]**	**Pb Total EU Annual Amount**; [to]**
Braking ECU	30	0,09	
Steering ECU	20	0,06	
Powertrain ECU	40	0,12	
Power Management (Generator Diodes)	9	0,14	
Other ECUs*	20	0,06	
SUM		**0,47**	**6,3**

*e.g. body control modules, climate control, seat memory, roof modules, etc.): 0.06g/vehicle.
** Assuming that 13.4 million vehicles are registered per year (ref: ACEA 2012, EU27+EFTA), the total amount of lead would be 13.4 million x 0.47g = 6.3 tons per year.

5. Please provide a roadmap towards ELV-compliance for those applications where the use of lead HMP solders is still unavoidable. Please break down the roadmap into steps to be performed and present and explain the related timelines.

Figure 7 shows a roadmap for the substitution of HMP leaded solders.

For sure Industry will continuously research for alternatives, however currently no alternative lead-free alternative 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.

Finally, all stakeholders involved to that contribution and especially JAPIA and "Four Electrical and Electronic Industry Associations in Japan", are prepared to actively continue research and development on that topic.
As automotive industry and EEE industry have a huge overlap in their supply chains, we would appreciate if EU commission would consider these aspects as well related to timing of related RoHS exemption review.

Questions & Answers

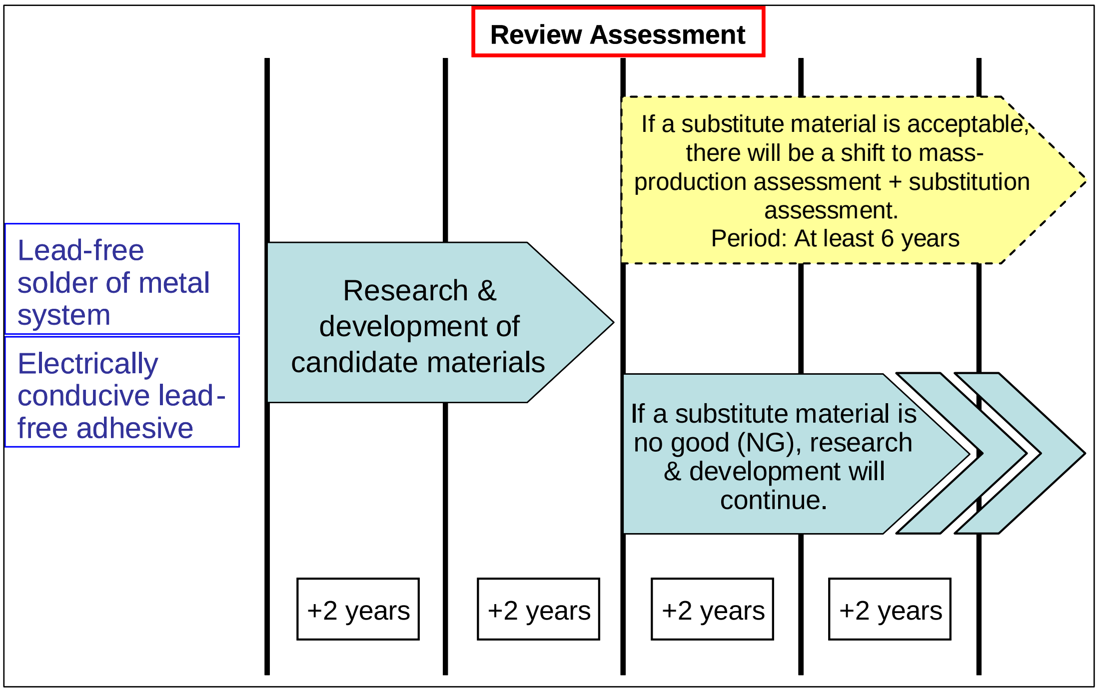


Fig. 7: *Roadmap*

Date: 4 November 2013

Questions & Answers

Annex

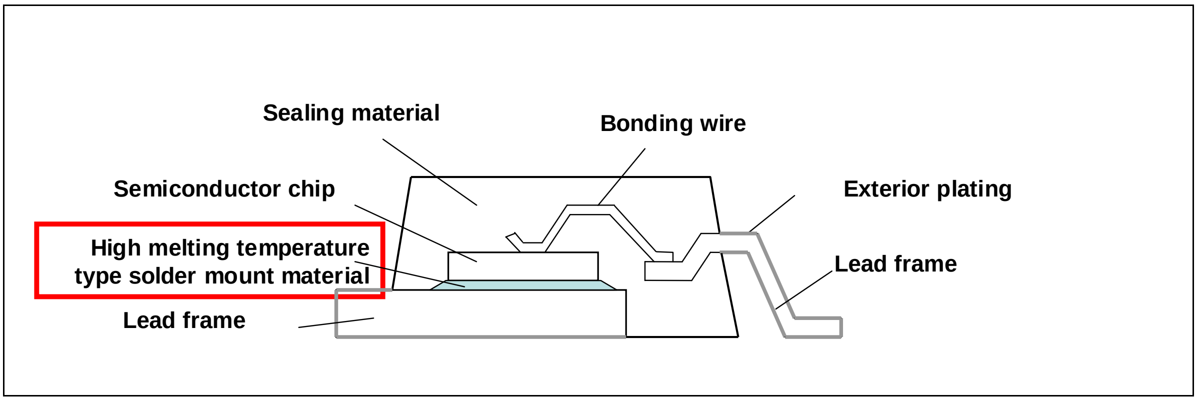


***Figure 1**:* *Schematic cross sectional view of power semiconductor*

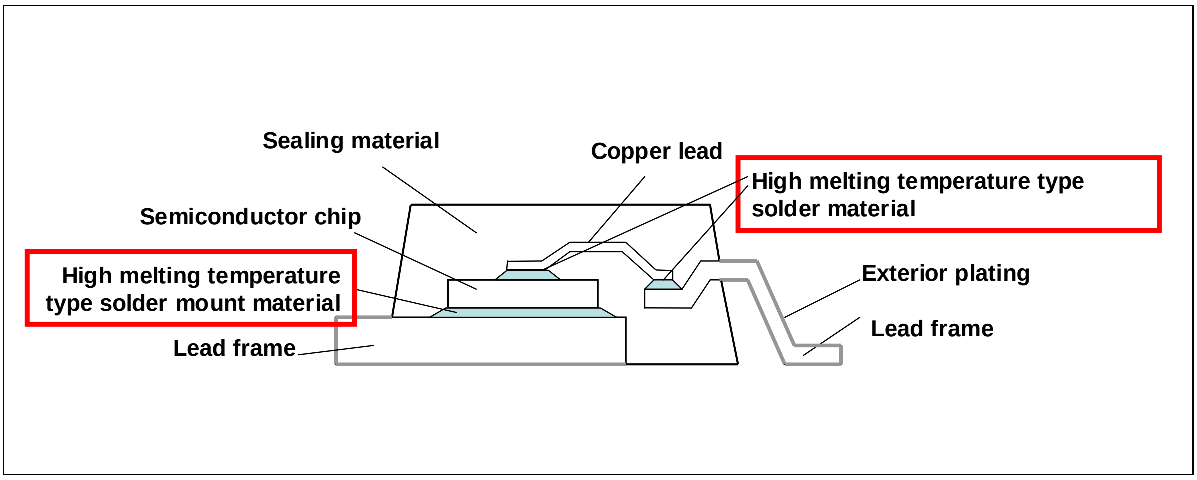


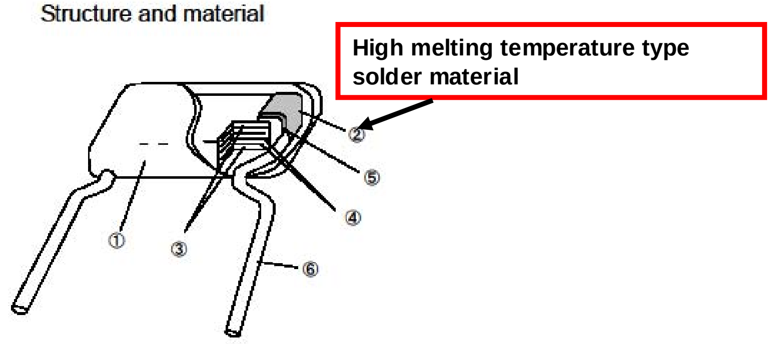
Figure 2: *Schematic cross sectional view of internal connection of semiconductor.*

Questions & Answers

Annex

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.

Figure 3: *Schematic view of capacitor with lead*

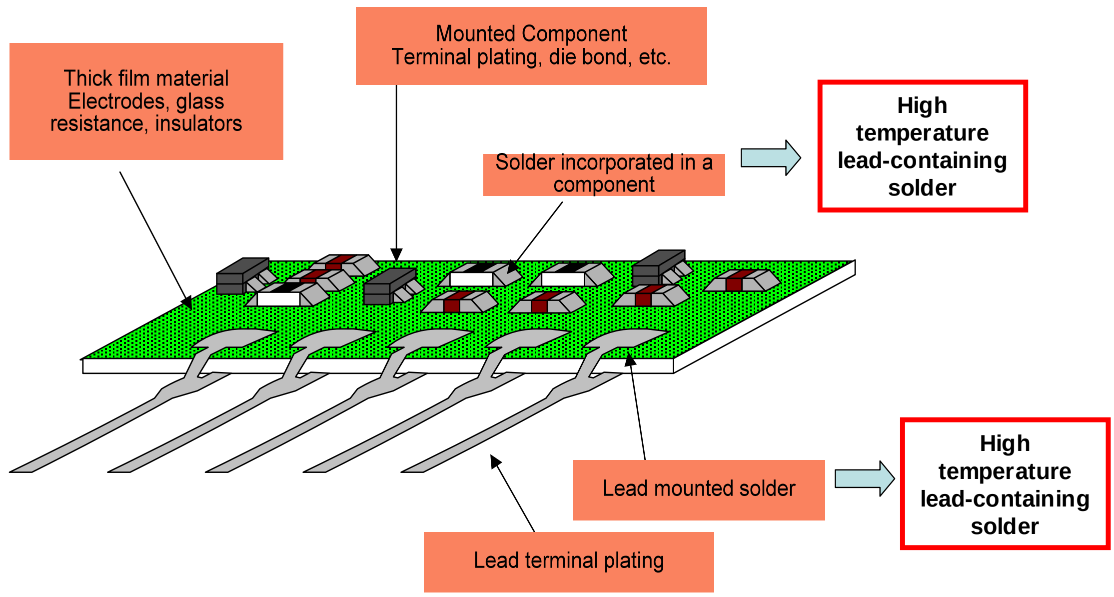


Figure 4: *Schematic view of circuit module component*

Annex

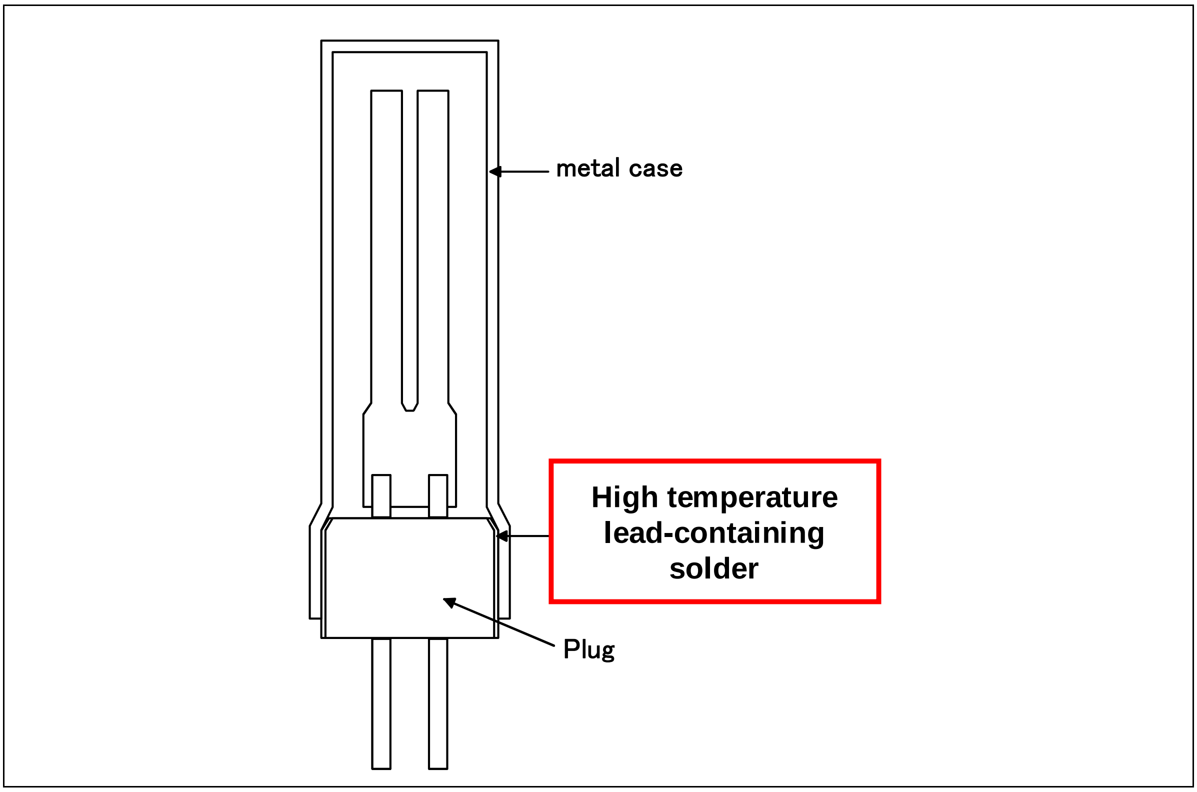


Figure 5: *Schematic view of crystal resonator*