Date : 1 April 2008

Dear Madam/Sir,

Please find enclosed the JBCE reply to the Öko Institut questionnaires concerning existing ROHS exemptions.

The reply consists of two parts:

- **Part 1: Reply to the exemptions questionnaires from the specific perspective of Category 8 & 9 equipment**

- **Part 2: Reply to the exemptions questionnaires**

- No. 3: Mercury in strait fluorescent lamps for special purpose
- No. 4: Mercury in other lamps not specifically mentioned in this Annex
- No. 5: Lead in glass cathode ray tubes, electronic components and fluorescent tubes
- No. 7(a): Lead in high melting temperature type solders (i.e. lead based alloys containing 85% by weight or more lead)
- No. 7(c): Lead in electronic ceramic parts (e.g. piezoelectronic devices)
- No. 13: Lead and cadmium in optical and filters glass

Please note that JBCE submitted a joint response with EICTA to the questionnaire concerning No. 6: Lead as an alloying in steel containing up to 0.35% lead by weight, aluminium containing up to 0.4% lead by weight and as a copper alloy containing up to 4% lead by weight.

Finally, JBCE is of course willing and ready to make further contributions and explanations.

Yours sincerely,

Lars Brückner
Chairman Environment Committee
Japan Business Council in Europe (JBCE)

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Comments related to the general and specific questionnaires of exemption 5

Japan Business Council in Europe

We expressly state the comments mainly concerning the necessity of continued application of exemptions and the difficulty of substitution for the consultation of RoHS exemption 5.
In this document, we make our comments concerning lead in glass of electronic components.

Note : As for the previous contribution coordinated and supported by JBCE, we would like you to give enough consideration to the fact that we refer to the presentation file (attached file (No.1) which JEITA, Japanese ICT Organization, contributed by the time of the final report on the revision of exemption no.11 "Electrical components which contain lead in glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs" of ELV Directive.

General Questionnaire

1. For which substance(s) or compound(s) should the requested exemption be valid?

   Lead in glass of electronic components

2. What is the application in which the substance/compound is used for and what is its specific technical function?

Please see the attached file *(No2).
In this excel file JEITA has summarized, through its best efforts, the results obtained from a survey of 57 electronic component manufacturers from Japan. However, it should be understood that this is not the opinion of ALL stakeholders.
We also would like to request you to treat this material as **"CONFIDENTIAL"** and thus not make it public.

3. What is the specific (technical) function of the substance/compound in this application?

   Please see the attached file (No2)

4. Please justify why this application falls under the scope of the RoHS Directive (e.g. is it a finished product?

   Please see the attached file (No2)

5. What is the amount (in absolute number and in percentage by weight) of the substance/compound in: i) the homogeneous material, ii) the application, and iii) total EU annually for RoHS relevant applications?

Please see the Attached file (No. 2) concerning applications.
However, regarding the amount put on the EU market, since the concerned electronic components are ultimately used in many electric and electronic products and there is no objective statistical material about the amount used or transported into the EU we cannot present concrete figures.

6. Please check and justify why the application you request an exemption for does not overlap with already existing exemptions respectively does not overlap with exemption requests covered by previous consultations.

   Not applicable – this is only for new exemption requests

7. Please provide an unambiguous wording for the (requested) exemption.

   Lead in glass of electronic components.

8. Please justify your contribution according to Article 5 (1) (b) RoHS Directive whereas:

8-1. Substitution of concerned hazardous substances via materials and components not containing these or elimination or substitution of concerned hazardous substances via design changes is technically or scientifically either practicable or impracticable;

There are materials and applications for which material substitute candidates exist and materials and applications for which no estimate of material substitutes exist at all.

Please see attached file (No.2) for examples of materials and applications for which there exists no estimate at all of material substitutes are shown in Please see attached file (No.2)*.

8-2. Negative environmental, health and/or consumer safety impacts caused by substitution are either likely or unlikely to outweigh environmental, health and/or consumer safety benefits thereof (If existing, please refer to relevant studies on negative or positive impacts caused by substitution).

１）Environmental load associated with manufacturing and refinement

We have found a report quantifying the environmental load of various metals with an index of "Total Materials Requirement (TMR)" produced by the Eco Material Center of the National Institute for Material Science.

Total Materials Requirement （TMR）: Total amount of global resources involved in production

"Efficient use of resources and influence on environment during the entire lifetime of the substance and material cycle"

http://www.lifecycle.jp/manual/coefficient_of_resources.pdf（P26）

According with this report, bismuth and niobium indicated as substitute materials for lead are estimated to have a larger environmental load due to their scarcity.

Comparison of TMR

lead	95	(comparative criterion)
bismuth	150,000	(approximately 1500 times)
niobium	1,400	(approximately 14 times)

Also, as bismuth is obtained as a by-product of lead ore, if bismuth is to be obtained, lead is always produced. If it is not used, a corresponding amount of energy is required to dispose it.

9. Please provide sound data/evidence on why substitution / elimination is either practicable or impracticable (e.g. what research has been done, what was the outcome, is there a timeline for possible substitutes, why is the substance and its function in the application indispensable or not, is there available economic data on the possible substitutes, where relevant, etc.).

Please see the attached file (No2) and (Data a-f).

10. Please also indicate if feasible substitutes currently exist in an industrial and/or commercial scale for similar use.

There are materials and applications for which material substitute candidates exist and materials and applications for which no estimate of material substitutes exist at all.

Please see attached file (No.2) for examples of materials and applications for which there exists no estimate at all of material substitutes are shown in Please see attached file (No.2)*.

11. Please indicate the possibilities and/or the status for the development of substitutes and indicate if these substitutes were available by 1 July 2006 or at a later stage.

Please see 8-1 and 8-2.

12. Please indicate if any current restrictions apply to such substitutes. If yes, please quote the exact title of the appropriate legislation/regulation.

    None

13. Please indicate benefits / advantages and disadvantages of such substitutes.

    See 8-2.

14. Please state whether there are overlapping issues with other relevant legislation such as e.g. the ELV Directive that should be taken into account.

    ELV exemption no. 11 ‘Electrical components which contain lead in glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs’ is an overlapping issue that should be taken into account it.

15. If a transition period between the publication of an amended Annex is needed or seems appropriate, please state how long this period should be for the specific application concerned.

As explained in Attached File (No.1), a roadmap for expiry of the current exemption cannot be provided at present because no alternatives for lead-containing glasses exist.
Even for the cases when a substitute material candidate exists or there is a newly developed material in place,
a great deal of time is required not only for development and reliability evaluation of the component but also for replacement and reliability evaluation of the final product application, furthermore as the range of products is as wide as to comprise almost all electric and electronic products and the number of pieces used is extremely numerous, if an appropriate transition period is not established there is a very real possibility of creating confusion in the market.
In order to establish an appropriate transition period there are high expectations that a survey will be conducted by the EU Commission for that purpose.
In this case JBCE is ready to actively cooperate with that survey.

Specific Questionnaire
1. Please specify in detail the “electronic components” in the wording above where lead is used in glass.
    Please see the attached excel file(No2).

2. Please state the amount of lead used per application, the lead content in the homogeneous material, the annual production volume as well as the number of applications put on the EU market annually in applications falling under the scope of RoHS for
b. electronic components (if possible specified in more detail, see question 1)
Please see the Attached file (No. 2) concerning applications.
However, regarding the amount put on the EU market, since the concerned electronic components are ultimately used in many electric and electronic products and there is no objective statistical material about the amount used or transported into the EU we cannot present concrete figures.

3. Please provide detailed information about the specific function and related performance criteria of lead in glass for
b. electronic components (if possible specified in more detail, see question 1)
    Please see the attached file(No2).

4. What technical characteristics do substitutes need to fulfil as a minimum requirement?
    Please see the attached file(No2).

5. Please provide evidence that manufacturers have put effort in research on alternatives for lead. What are the alternatives to lead and which ones are (likely to be) used as substitutes? Are there any results about strengths and weaknesses expressed in results relating to (technical) performance criteria?

Please see the attached file(No2).

6. Are manufacturers still investigating alternatives?

b. If no, please explain and justify why no further research has been undertaken against the background that the RoHS Annex is subject to regular revisions.

As shown in the attached file (No.2) and (Data a-f), no effective substitute materials exist for the application. However, if in the future substitutive materials can be developed, electronic component manufacturers will proceed substitution.

7. Assuming the current exemption will be given an expiry date, what date do you think is technologically feasible for industry?

As explained in Attached File (No.1), a roadmap for expiry of the current exemption cannot be provided at present because no alternatives for lead-containing glasses exist.

Attached file No,1

Q1. Please specify the applications of lead in components in which the lead is actually part of a homogeneous material, which itself (not only parts of it!) is a glass. Please also provide the definition of “glass”, on which you base your answer including the source of this definition.

◆Please specify the applications of lead in components in which the lead is actually part of a homogeneous material, which itself is a glass.

Materials	Applications	Components
Borosilicate glass	▪ Pre-coating for thick film resistors ▪ Surface protection coating ▪ Vacuum (adhesion) assurance ▪ Resistor binder (adhesion assurance for ceramic base materials) ▪ Electrode binder (adhesion assurance for ceramic base materials)	▪ Varistors ▪ Chip resistors ▪ Strain sensors ▪ Bridge rectifying devices ▪ Power transistors ▪ Power thyristors ▪ Quarts oscillators

◆ Please also provide the definition of "glass".

Lead-containing borosilicate glass used for electrical components refers to amorphous solid mainly consisted of SiO_2, B_2O_3, Na_2O, or PbO, which indicates glass transition phenomenon.

Q2. Please specify the cases of lead applications similar to the trimmer potentiometer ones particular where lead is NOT part of a homogeneous glass material, although the homogeneous material may contain glasses. This should apply to most thickfilm technologies, in those components which contain lead in resistive layers? What about capacitive layers and the thickfilm layers in resonators? Which other components might be affected? What about the functionalities where lead (as lead oxide?) provides the adhesive functionality of the thickfilm layer to substrates like ceramics? The thickfilm layer should be considered as the homogeneous material. Please indicate the concentration of lead in these materials, and describe the homogeneous material in case you do not agree with the proposed homogeneous material definition.

[The two applications of the glass including lead]

Application 1;

The "Lead oxide ruthenium (metallic oxide)" is studded in the "Glass" contained in a resistor that the end user obtains, and the both of them consist a homogeneous resistance layer. The glass and the lead oxide ruthenium in this resistance layer cannot be separated from each other and the layer looks like glass.

Such glass with the ruthenium forms partly the thick film contributing itself to the resistance layer’s function. We have never found any proposal of substitution for the materials with this function.

The thick film is used as an insulation film. In this case, Insulation materials be used instead of the ruthenium oxide, and it is offered to the end user, as an insulation parts and the glass materials for insulation protection film. there is no alternative material to form a such insulation film.

Application 2;

(It is shown in Q2) It is the other application to use the glass including lead to connect a base material such as ceramic etc. with electrodes (or, to seal them) . In this case, the lead is contained in the glass on the several % level in order to lower the melting point of the glass and to secure the workability,

Such glasses are generally adopted in a lot of electronic parts. If any material is found , that can secure a certain level of low melting point, strength in joint, sealing characteristic, electrical properties and working properties, etc. for this application, it is possible to obtain the substitution and actually some substitutions are being developed.

- Please specify the cases of lead applications similar to the trimmer potentiometer ones (thickfilm layers).

Materials	Applications	Components
Ruthenium lead oxide + (Borosilicate glass)	▪ Resistors	▪ Chip resistors ▪ Strain sensors
Conductive materials (Au, Ag, Pd, etc.) + (Borosilicate glass)	▪ External electrodes	▪ Chip resistors ▪ Varistors

- This should apply to most components formed with thickfilm technologies.
  - This should apply to capacitive in resonators.
  - This should also apply to the functionalities where lead provides the adhesive functionality of the thick film layer to substrates like ceramics.

- Indicated below are examples of lead concentrations in thickfilm layers and glasses in use.

Materials	Applications	Lead concentration (%)
Borosilicate glass	▪ Surface protection coating ▪ For electrodes ▪ Resistor binder (adhesion assurance for ceramic base materials)	45 to 50 1 to 57 3 to 30
Ruthenium lead oxide	▪ Resistor	56.9

Q3. What are the total amounts of lead involved?

* Per vehicle produced in 2001 and the latest year for which such data are available?
* Per year in all vehicles registered in Europe in 2001 and the latest year for which such data are available?
* What is the technical trend and how will it affect the amounts of lead involved?
* Please differentiate for lead in glasses (question 1), lead in thickfilm layers (question 2) and lead in the different ceramics applications in components.

* As we are not manufacturers of cars and in-vehicle equipment, it is difficult to present the requested data. Instead of the data, we present here the list of major examples of in-vehicle applications with piezo-electric ceramic parts.

Microsoft Office Excel ワークシート **<- Click this icon**

Note to this attached data;

*The component installing rates (Ave. Ratio.) and the usages are estimated.

*This list is not collectively exhaustive for applications of all the concerned components.
For instance, "High-pressure capacitor (with dielectric ceramics)" and "PTC thermally sensitive resistor (with semiconductor ceramics)" contain lead besides parts with piezo-electric ceramics.
Ceramics with lead are used for a lot of applications that support many functions of the car.

*We are ready to submit illustrations on the applications of ceramics that contain lead.

Applications of piezo-electric ceramics

1)Actuator Fuel Injection(for diesel engine) ,Piezo-electric motor

2)Sensor Knocking detection (for engine) , Load detection (for body)

Impact detection (air backing system) Acceleration detection (anti-theft)

3)Resonator/Filter Electric control equipment (engine,/In-vehicle electronic equipment)

4)Buzzer Warning and sounding (console and control panel)

5)Voltage converter (booster transformer) Backlight (console), HID headlamp power supply(light)

Applications of PTC ceramics

1)Electrical and electronic control circuit (current protection, motor starter, and thermometric sensor)

2)Heating in a car (source of heat)

Applications of dielectric ceramics

1) Electrical and electronic control circuit

2) Ceramic capacitor for high pressure (exceeding DC250V and AC125V).

Q4. Which alternatives to the lead-containing ceramics (piezo and others) and to the use of lead in glasses and/or in thickfilm layers in components have been researched or are available on the market? Please explain with respect to their viability as legally compliant substitutes in vehicles. .

Piezo-electric ceramics

* Piezo-electric ceramics with lead achieves a certain levels of the following index; Piezoelectric Strain Coefficient (d constant) and Curie temperature (Tc).

* A non-lead piezo-electric typed ceramics, which we see might be available in the development phase, is a niobate-alkali typed ceramics.
Piezo-electric characteristic of this alternative ceramics;
Piezoelectric Strain Coefficient (d constant): 50pm/V-300pm/V
Curie temperature (Tc): 100℃-280℃
These values do not satisfy a required alternative performance of piezo-electric ceramics with lead.

Conclusion;
We see no viable substitutes for piezo-electric ceramics at the present time.
Any substitution has still not appeared on the stage where we can easily obtain it in the market.
However, some researchers are now positively proceeding evaluation of materials to be alternative, and some ceramic resonator applications can be replaced by quartz vibrators.

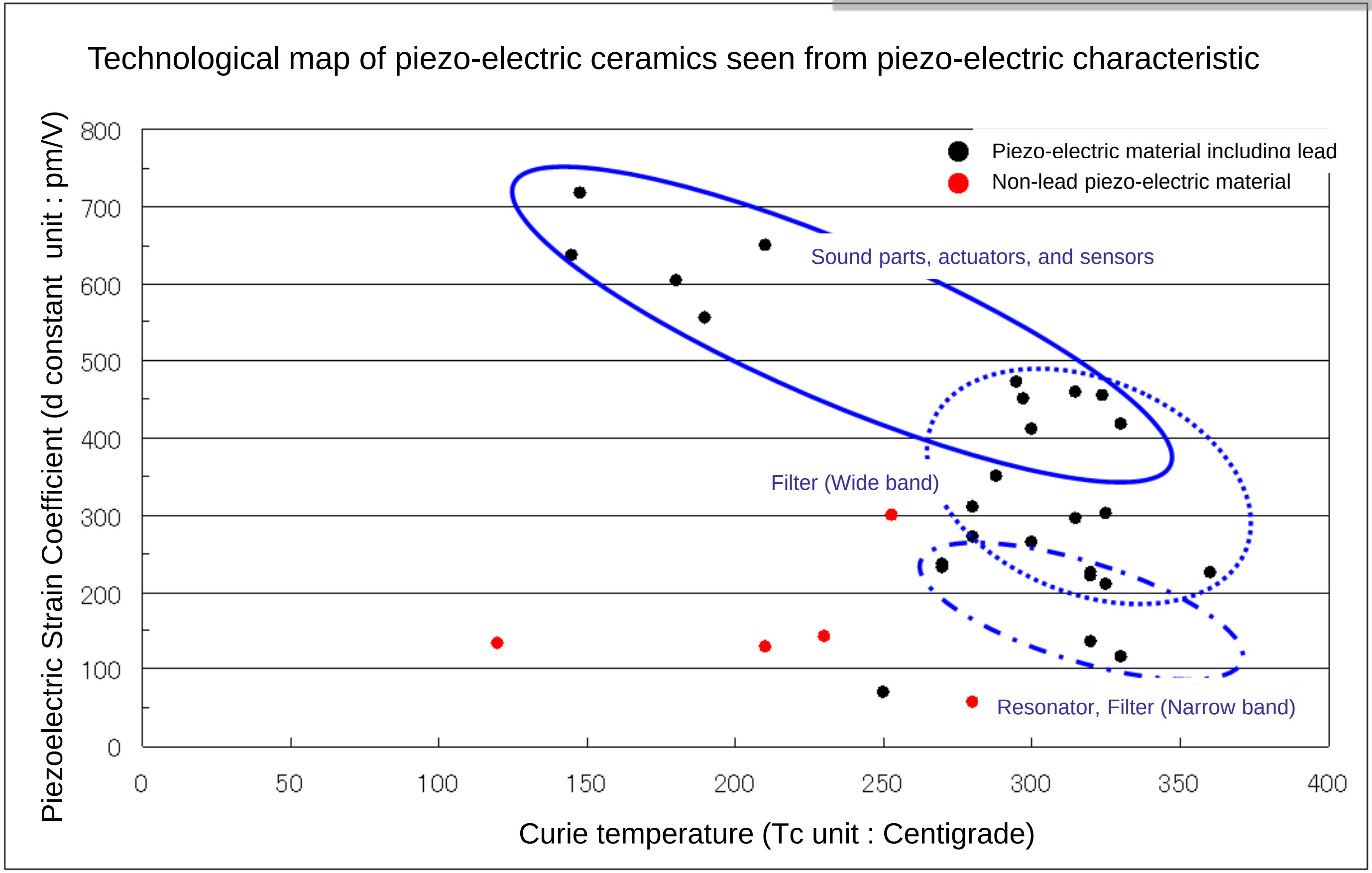
Piezo-electric ceramics

The levels of Piezoelectric Strain Coefficient (d constant) demanded by in-vehicle equipment

Sound parts, actuators, and sensors: 400pm/V or more
Filter: 100pm/V-400pm/V
Resonator: 100pm/V-200pm/V

Curie temperature (Tc) demanded from in-vehicle equipment
260℃～350℃

Current candidate materials for the alternative cannot have the same function as a resonator and a filter because each characteristic is insufficient for the required performance.



PTC ceramics

* PTC ceramics with lead can have a Curie temperature (Tc) at enough level for the thermally sensitive resistor or car heater

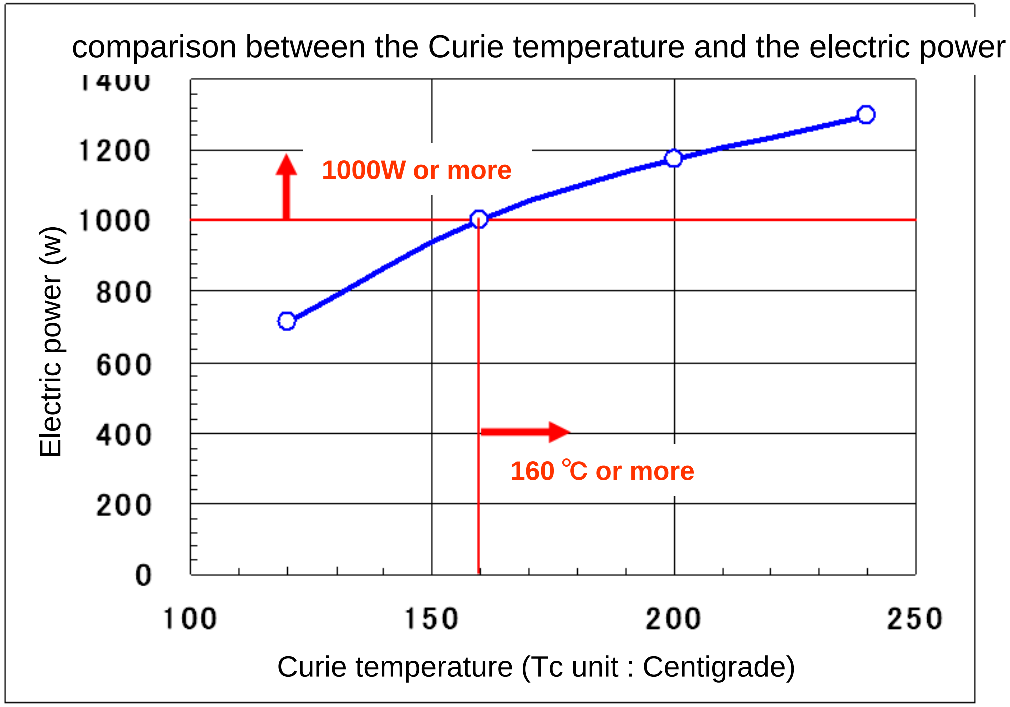
* The following item a) -d) are now proposed as alternative materials of PTC ceramics for the heater.
Because the Curie temperatures of all these alternative ceramics are not above 160℃ at maximum, they cannot make performances enough to replace PTC ceramics with lead.
It has been reported that the Curie temperature of item a) (BT-NBT) was improved up to 155℃but the mass production technology has not been established yet.

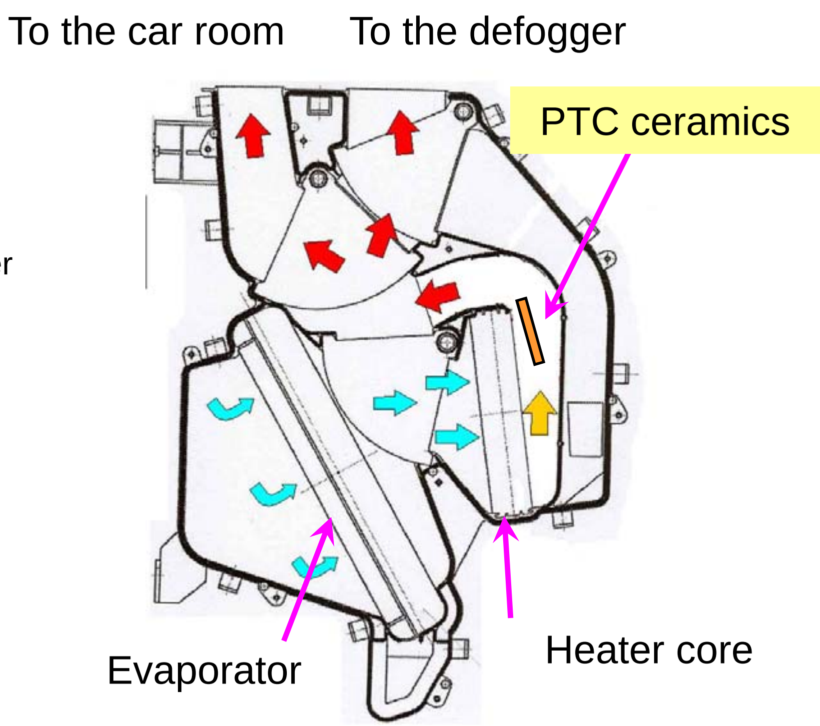
a) BiTiO3-(Bi1/2Na1/2)Tio3 （BT-NBT）
b) BiTiO3-(K1/2B1/2)Tio3 （BT-KBT）
c) BiTiO3-BiFeO3 （BT-BF）
d) BiTiO3-NaNb O3 （BT-NN）

→ Conclusion;
We see no viable substitution of PTC ceramics at the present time.
There can be candidate materials for the alternative,
However, such ceramics does not seem viable in the market now.

PTC ceramics

Specification demanded by in-vehicle heater
- Size : 200mm × 100mm × 10mm
- Electric power : 1000W or more
- Curie temperature (Tc): 160℃ or more





Dielectric ceramics

- We can always use the dielectric ceramics with lead stably in manufacturing a high-pressure capacitor because it can provide few dielectric loss and calories loss.

*Barium titanate and strontium titanate are now proposed as the substitution.

*Barium titanate cannot contribute a stable function to the high-pressure capacitor because it gets heat as the dielectric loss gets larger in the capacitor.

*Strontium titanate, which permittivity is smaller, needs the size of ten times as large as the given size of the dielectric ceramics with lead in contributing the sufficient function to the capacitor

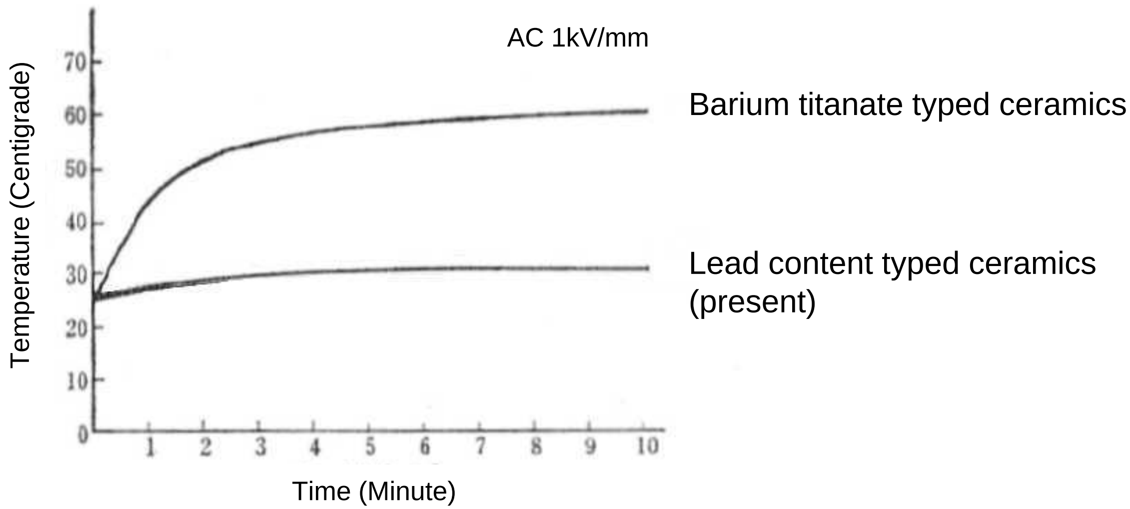
Conclusion;

We see no substitutions of dielectric ceramics with lead for a high-pressure capacitor at the present time. It is unavailable in the market.

We have already found that the alternative materials for the dielectric ceramics with lead used for other ceramic capacitors than a high-pressure capacitor and some of them have already replaced it
However, some time enough to completely replace it should be given because such ceramics are used widely and generally in the market.

Dielectric ceramics

Generation of heat comparisons of ceramic materials



3-d-表1　高圧コンデンサ用材料比較

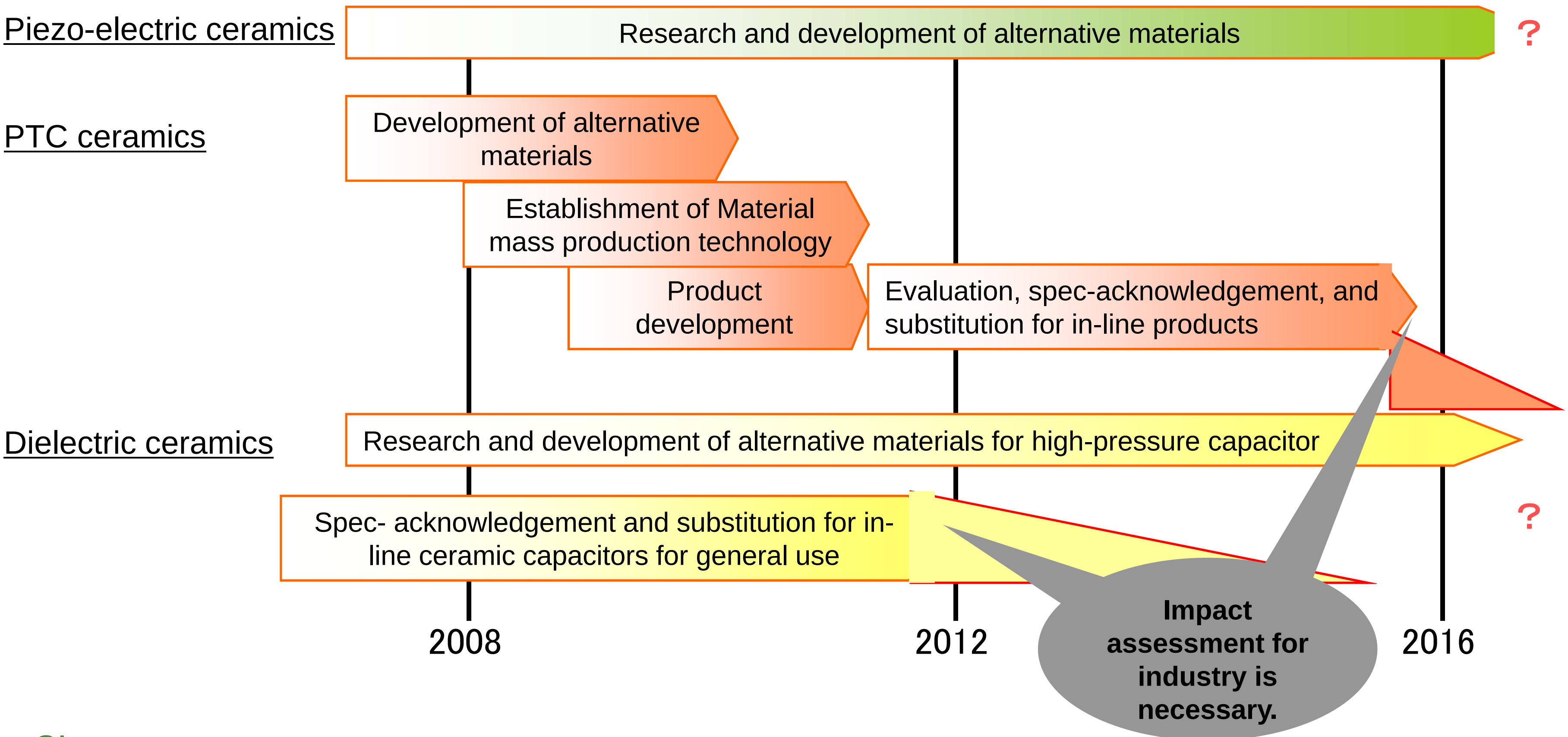
	Permitivity	Dielectric loss (%)	DC Breakdown Voltage (kV/mm)	AC Breakdown Voltage (kV/mm)	Impulse Breakdown Voltage (kV/mm)
Lead content ceramics (present)	2700	0. 04	15. 3	8. 0	8. 0
Barium titanate system ceramics	3000	0. 80	11. 8	6. 7	6. 0
strontium titanate system ceramics	200				
Remarks	Largeness is good.	Smallness is good.	Largeness is good.	Largeness is good.	Largeness is good.

Glass

Glass alternatives under research include borosilicate zinc glass and borosilicate bismuth glass, resistor alternatives include bismuth ruthenate, sodium ruthenate, strontium ruthenate and others. However, application to electrical components still includes many difficulties, and no successful application has been reported. Alternatives with properties equivalent to lead-containing glasses/thick film layers are not available on the market.

Q5. Please provide a roadmap to legal compliance for the currently unavoidable uses of lead in glasses, in thickfilm layers and in ceramics of electrical components.

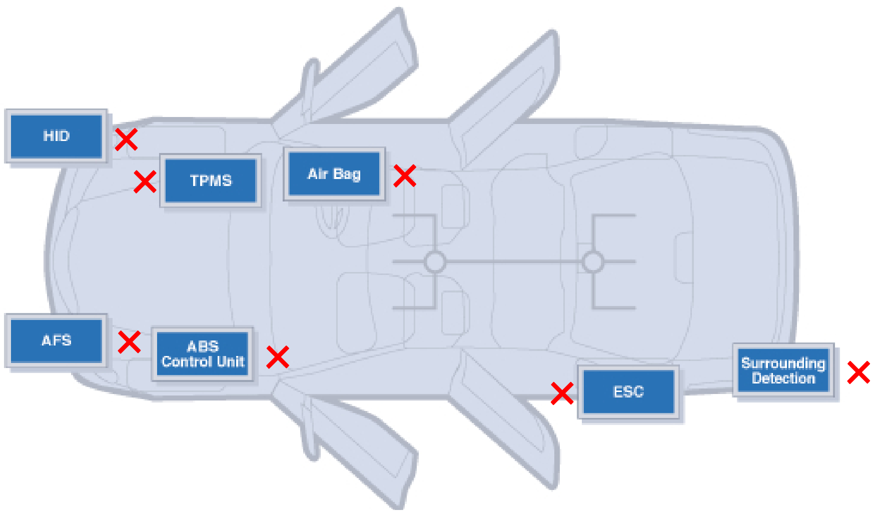
Q6. Please indicate where the use of lead in components (questions 0 and 0) can be avoided. .



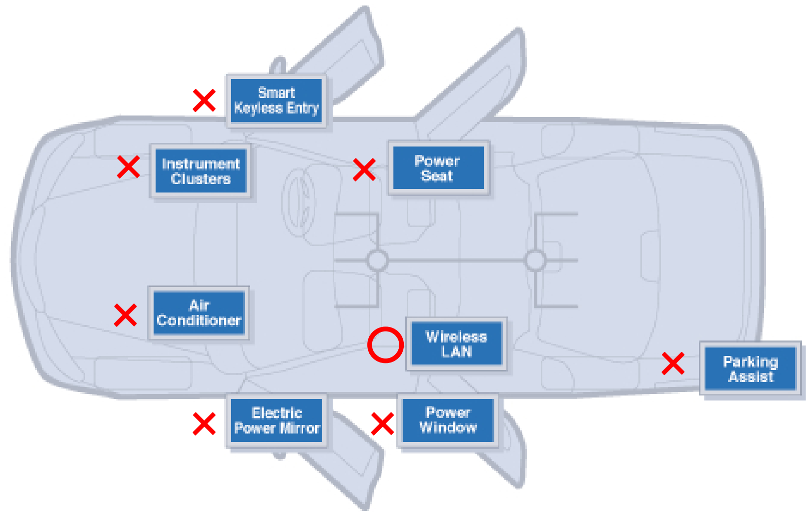
Glass

Such a roadmap cannot be provided at present, because no alternatives for lead-containing glasses, thick film layers and ceramics are available as described in Q4.

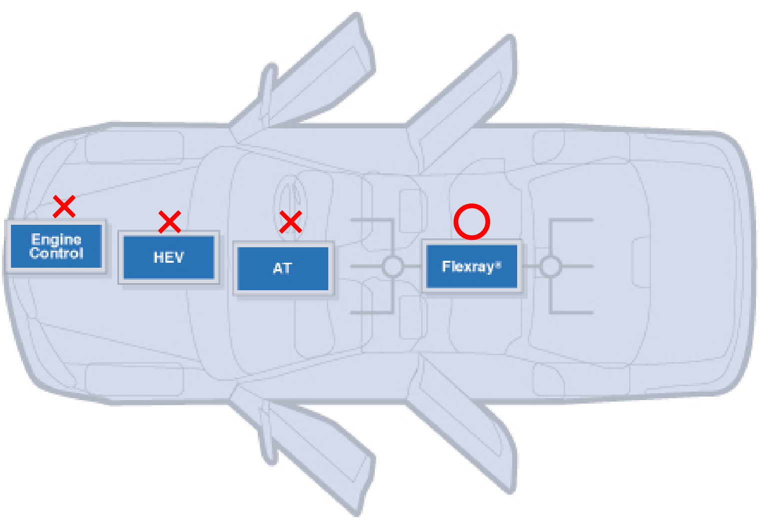
Safety



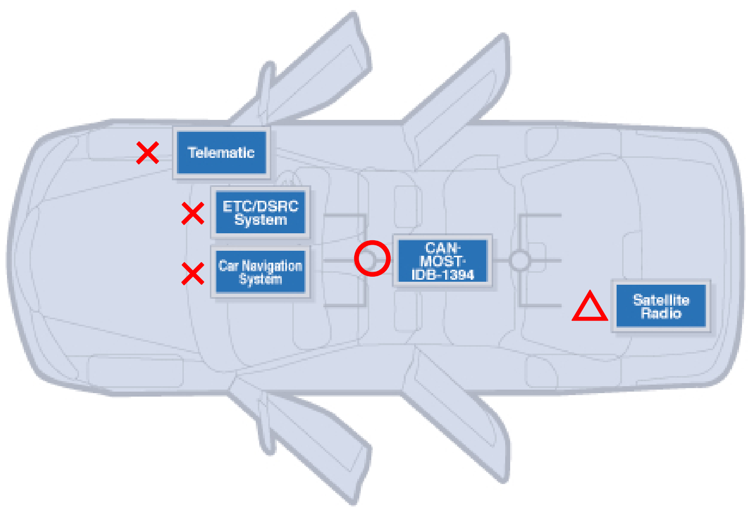
Comfort / Accessory



Power train



Information



×: adopted electronic parts with lead which are difficult to be replaced

Q7. In order to avoid insecurities for the industry, a new exemption might either have to replace or to complement the existing exemption no. 11 of the ELV Directive. This exemption would have to cover the cases under question 2, where the use of lead is unavoidable. A possible wording for this exemption might be

Electrical components which contain lead in a thickfilm layer with resistive (…) functionalities or in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs

Please give your opinion on this possible exemption proposal.

Possibly, the exemption has to be limited to specific components if the use of lead in such components is not generally unavoidable (question 4).

We can generally support the proposed wording which deliberately considers the realities.

（Please give your opinion on the possible exemption proposal.）

「Electrical components which contain lead in a thickfilm layer with resistive, conductive, insulating, dielectric, magnetic or other functionalities, or in a glass or ceramic matrix compound except glass in bulbs and glaze of spark plugs.」

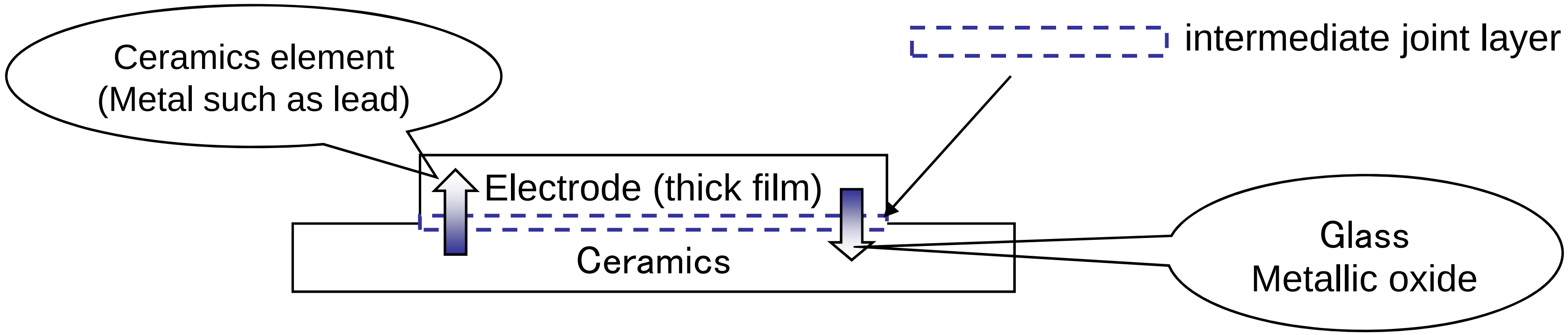
[A Question for the proposal]

The intermediate joint layer gets completed in the boundary of the ceramic part and the electrode part as some of the constituents of the both parts penetrate into the layer. Consequently, this intermediate joint layer gets integrated with the ceramic and the electrode part and they cannot be separated. Thus these three layers form one homogeneous material. (Refer to the figure below).

The proposed wording admits "lead in the ceramic material used for electronic parts is exempted from ELV directive". Thus it admits a possibility that the lead is contained in the ceramic part side.

The lead, which penetrated from the ceramic part into the electrode part in jointing, may be detected in this homogenous material part after all. This lead constituent is originally from the ceramic part.

Does the proposed wording assume that such lead is under the exemption?



Such joint using the thick film absolutely accompanies this phenomenon
. Therefore we propose that the content of the lead should be exempted from the ELV directive because such joint is one homogeneous material that the ceramics and the thick film are integrated.

Q8. In case you wish to base your request for continuation of exemption no. 11 on environmental grounds, please answer the following questions:
What happens to the different types of components which contain lead in glasses, thickfilm layers or in ceramics in the end-of-life (EoL) processing? Do they end up in the shredder light fraction, in the steel fraction, …? If so, what happens to the lead in these components? Is it recycled as metal or alloy, or does it end up in landfill sites? If such components are separated before shredding, what happens to them and how much of the lead is actually recycled as alloy or metal? Please provide the corresponding information with respect to the environmental aspects mentioned above under points on page 2 f. Please include the sources of your information. .

*We see that any public process where lead is recycled and recovered from electronic parts has not been established yet, and that, therefore, the lead as waste may go to landfills unless it is collected for other reasons.

- We see it is possible to recover metallic elements from the components by melting them at a certain ultra high temperature. However we are afraid that the consumption of much energy for such disposal may cause adverse effects on the environment. It is necessary to develop a recycling process which can minimize adverse impacts on the environment besides development of the alternative material.

*Many problems may happen in re-use of electronic components and it is difficult to resolve them in the quality control and re-projection into a manufacturing process

*Miniaturization of electronic components may lead to reduction of them. The amount of use of the chemicals may be controlled through the miniaturization.

JEITA

Q9. How would the environmental situation change in case technically viable alternative components without lead in glasses or in ceramics are available? .

- Vehicles (equipment) with fewer adverse environmental impacts may keep supplied at a present technological level if all necessary alternative materials are truly viable.

- It is necessary to consider further prohibition of use of lead together with the following possible measures

1) We are afraid that we use more energy to try to get the rare materials as alternative, as more possibility of adverse environmental impact on the earth may increase

Example 1: Bismuth and such kind of metals have been used as by-products from lead.
more burden of proper disposal of unnecessary lead may be caused
after the lead ore is mined and refined in order to obtain certain amount of bismuth

Example 2:When we must use rare resources such as niobium in a few places on the earth
as alternative materials, the resource exhaustion may happen and
the burden of mining and transportation may increase.
We are afraid that the unstable supply of them may bother us

2) Any methods for Long-term assessment of harmfulness of rare materials, recovery of rare materials and for protecting workers from the harmfulness have not been maintained.

3) Scrapping of a large amount of equipment, parts and materials that contain lead, may occur although that events could be finished in a short term over the world.

* The nowadays, when idea of EMS and CSR are regarded as significant, is encouraging Japanese electronic industry to be pioneer to replace lead containing products with the alternatives. Nevertheless, the major reasons why some substitutions are now reserved are partly because “ No technology for the substitution is found" and “specifications of repair parts for existing products cannot be changed immediately"
  Most of repair parts may run out the product longevity, therefore, the cost for the alternative technology for the repair parts is difficult for the manufacturers to be secured. The repair parts manufacturers should keep manufacturing and supplying them unless the contract for supply to their customers terminates

* In laying down further use restrictions, it is necessary to evaluate the priority where to restrict by the extent of "Risk“ which "Hazardous property" multiplied by "Danger of the exposure“ is. And additionally, it is necessary to consider "Effectiveness to environmental measures".
  For instance, technologies for engine control, fuel injection control and Electric vehicle of the next generation type are indispensable for eco-friendly cars to meet environmental standards at which Europe aims. These researches and developments for the practical application have been or are being executed by using electronic parts with lead.
  Restrictions that focus on only the hazardous property of lead may cause adverse environmental performance improvement.

For such reasons mentioned above, we conclude that it is necessary to consider decreasing adverse impact on the environment from an overall viewpoint.

Thank you

有倉　陽司 (Yoji ARIKURA)
e-mail: arikura@jmceu.org

Data a

Comparison Data of the Withstanding Surge Current Test

Each n＝5

Product number	Current product A (glass frit for lead-based electrode)	Comparative product (glass frit for non lead-based electrode)
Test values (rated value)	1000A×1time	
V1mA rate of change	positive direction 0.20% negative direction -1.20%	positive direction 0.80% negative direction -8.50%
Withstanding surge current	1500A	1000A

In case of using an electrode with non lead-based glass frit, there is no balance threshold value relative to the rated value as the withstanding surge current deteriorates.

Data b

Comparison Data of the High Temperature Load Life Test

Test 1 each n=5

Product number	Current product B (glass frit for lead-based electrode)		Comparative product (glass frit for non lead-based electrode)	
Test conditions	85℃, Current application rate DC90%, 1200 hours			
V1mA rate of change	positive direction	2.40%	positive direction	1.30%
	negative direction	0.60%	negative direction	0.00%
Withstanding surge current	1500A		1000A	

A significant difference was not found in the 85℃ high temperature load test.

Test 2 each n=5

Product number	Current product B (glass frit for lead-based electrode)		Comparative product (glass frit for non lead-based electrode)	
Test conditions	125℃, Current application rate DC10%, 1150 hours			
V1mA rate of change	positive direction	4.80%	positive direction	3.60%
	negative direction	-1.50%	negative direction	-9.20%
Withstanding surge current	1500A		1000A	

The non lead-based product shows a fluctuation range close to ±10% of the decision criterion of V1mA rate of change when the period of high-temperature load test exceeds 1000 hours.

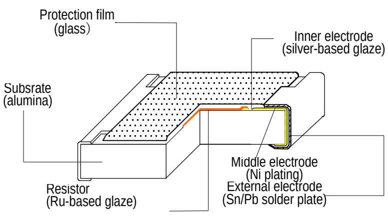
Data c

Substance / Usage

Type of substance	Usage	Reduction difficulty level
Glass frit contained in a thick film material forming electronic device	Resistors, capacitors, chip coils, chip inductors, resistance networks, capacitor networks, hybrid ICs	**Substitution by 2008 is not assured**

Reason for usage

Portion of usage (Sketch)	Reason for usage
Ex) Chip resistance	Material and characteristics of glass frits for thick film technology



	Pb glass	Zn glass	P-Sn glass	Na-Al-P-B
Compatibility of component	○	△	△	○
Low softening temperature	○	△	○	○
Thermal expandability coefficient	○	○	○	△
Climatic conditions	○	○	△	△

The lead-based glass is composed to have the flexibility to satisfy the characteristics required for thick film materials and it is inexpensive. Therefore, it is used for many glass frit compositions.

Substitution difficulty

Though we have examined many alternative glass frit compositions in the past, they do not satisfy the requirement for glass frit mentioned above. For example, P_2O_5-SnO-based glass and Na_2O-Al_2O_3-P_2O_5-B_2O_3-based glass have been developed, though they are not practical in application as they are inferior to lead-based glass in Climatic conditions.

There are many glass frit compositions containing lead in the world. A long period of time will be required to develop lead-free glass frit to replace them.

Explanation of Technical terms

Technical terms	Explanation

・Thick film technology	・Form the pattern out of functional material such as conductors, resistors, and dielectric bodies on substrates using screen printing technology. The material is processed in paste form and calcinated at around 800℃.
・Glass frit	・Glass finely ground into powder form

Data d

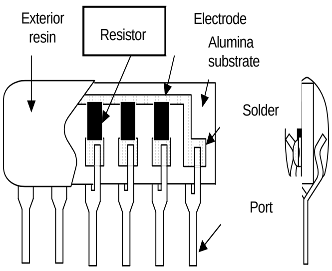
Substance / Usage

Type of Substance	Related Usage	Reduction difficulty level
Lead in thick film resistors as the resistance component of various resistance parts	RC networks , potentiometers, hybrid ICs, chip resistance , chip resistance networks, chip RC networks , chip capacitor networks , chip resistance arrays, trimmer potentiometers, etc.	A (Substitution by 2008 is impossible)

Reason for usage

Portion of usage (Sketch)

(Example)
Resistance network



Reason for usage

Thick film resistors are used by printing a resistive paste of thick film on the alumina substrate and calcinating it. Thick film resistors cannot be produced without lead.

Table1 shows the ingredient example of typical resistive paste.

Name of material		e (wt%)
Conductive materia	Pb2Ru2O7	15～20
Glass frit	Pb-Si-B-O	20～45
Vehicle	resin, solvent	30～45
Metal oxide	MnO,CuO etc	0.1～5

Table 1

Lead (Pb) is found in lead ruthenium oxide ($Pb_2Ru_2O_7$) of conductive materials and glass frit.

The range of resistance value of lead (Pb) is as wide as 10^{-3} Ω・cm～10^4Ω・cm.

It is the key material for resistors with TCR characteristics of -55□～150□ and ±100ppm～±250ppm.

Lead ruthenium oxide has a wide range of resistance value and the fine grain and coarse grain are well balanced, which enhances the current withstand and contains the contact resistance. See Figure 1.

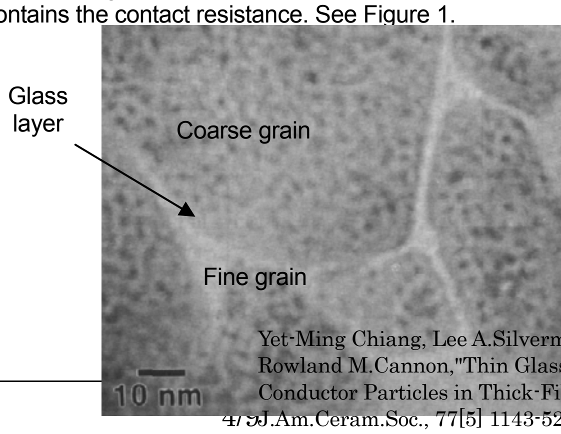


Figure 1

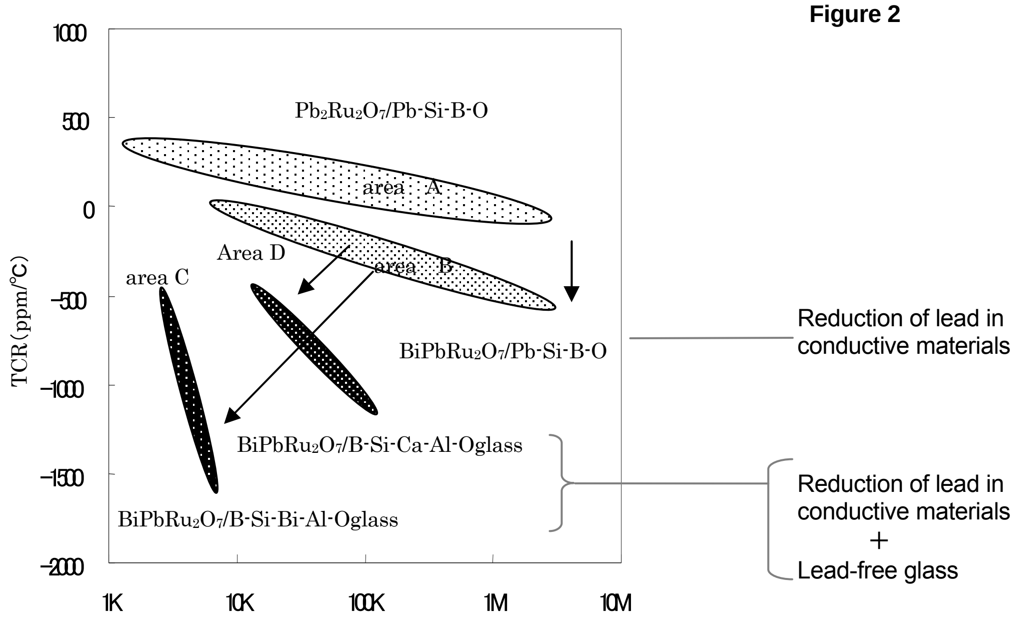
Yet-Ming Chiang, Lee A.Silverman, Roger H.French and Rowland M.Cannon,"Thin Glass Film between Ultrafine Conductor Particles in Thick-FilmResistors", 479J.Am.Ceram.Soc., 77[5] 1143-52 (1994)

	Lead-containing glass has a wide range of softening point and wettability with conductive particles, forming a thin glass layer between the particles easily, which is deeply connected with the good TCR properties.

Substitution Difficulties

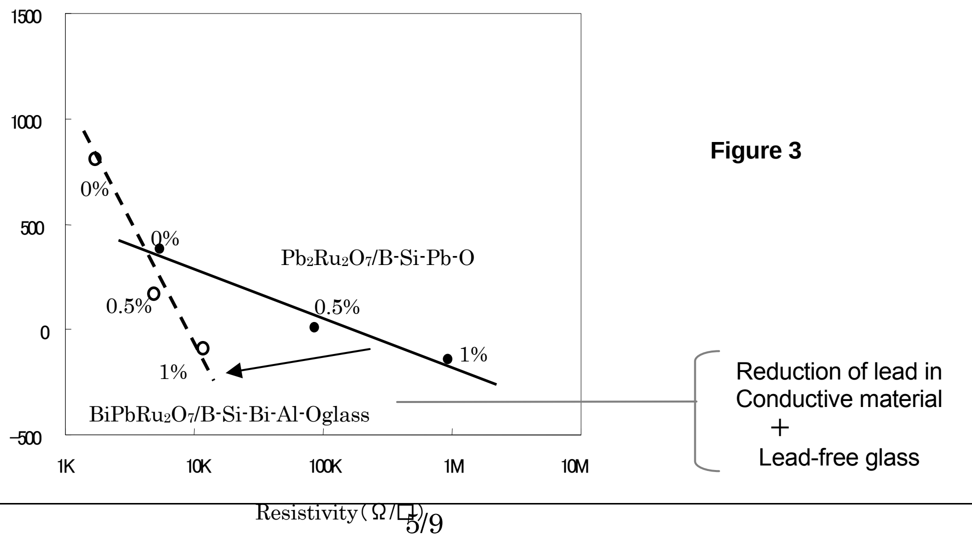
When we substitute a part of lead of lead ruthenium oxide with Bi, the area A changes into Area B as shown in Figure 2 and the range of resistance values shrinks, deteriorating TCR properties. Moreover, when we substitute the material of this glass with Ca-Al or Bi-Al, it changes into Area C or Area D and the resistance values and TCR properties deviate from the range of use.

Figure 2



Metal oxide UMnO or CuO) is used as an additive to adjust TCR to be closer to a particular required area.
As shown in Figure 3, the non lead-based conductive material and glass material violates such properties of metal oxide（MnO or CuO）.

Figure 3



Alternative non lead-based substances used in the above evaluation are the most feasible option.

Explanation of technical terms

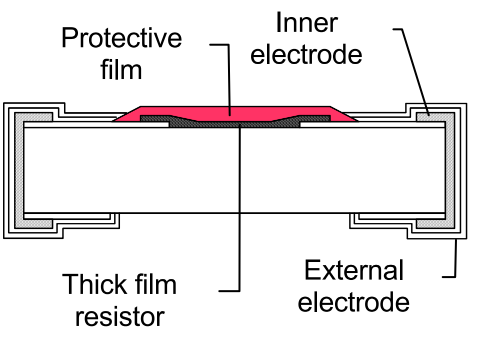
Technical terms	Explanation
Paste	Liquid in which large amount of fine solid particle is scattered.
TCR	Coefficient to indicate the fluctuation of resistance values when the ambient air temperature rises by 1℃. Resistance temperature coefficient。
Contact resistance	Electrical resistance present between the contact surfaces of two substances
Softening point	Temperature at which the substance softens
Wettability	Penetration and blending of glass into the gap of conductive particles

Data e

Item / object

Item	Object	Reduction difficulty level
Lead contained in glass which is a thick film insulator	Fixed metal glaze flat chip resistors, Chip-shaped R networks , multiple chip-fixed resistors Chip-shaped RC networks , chip–shaped C networks etc	Substitution by 2008 is not assured

Reason for usage

Parts of usage	Reason for usage
Fig. 1 shows the structure of a square chip resistor used in glass as thick film insulator. The protective film contains a lead compound as material and the protective film is made of two layers of pre-coated glass and protection-coated glass.  **Fig.1 Structure of a square chip resistor**	**Pre-coated glass** 1. Low fusing point When correcting resistance values of thick film resistors by trimming, the pre-coated glass must be able to be cut with the heat of laser trimming. Therefore, the pre-coated glass formed on the thick film resistor needs to be sintered at a relatively low temperature (600°C). 2. Moisture & Acidity resistance Pre-coated glass is required to control the fluctuation of resistance values due to moisture and acid etc. Due to these reasons, lead-based glass is used. **Protection coating** Use of non lead-based alternative product is possible.

Reason of difficulty of substitution

Pre-coated glass
Due to the absence of materials superior to lead-based substances in moisture resistance and acidity resistance.

Characteristics of substitute glass ○ : Excellent △ : Slightly poor × : Poor

Material	Trimming properties	Acid resistance	Moisture resistance	Heat resistance
Lead glass	○	○	○	○
Bi Glass	○	×	△	○
P glass	○	×	△	○

Explanation of technical terms

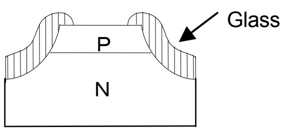
Technical terms	Explanation
Pre-coated glass	Material used to control the fluctuation of resistance values in post-processes etc.
Coated glass	Material used to protect resistors
Laser trimming	Method to correct the resistance values to obtain the given resistance values

Data f

Substance／usage

Type of substance	Related products	Reduction difficulty level
Lead-based glass (Pb glass) : Used for the protection of surfaces of semiconductor chips	Bridge rectifying devices, power diodes , power thyristors, power transistors etc	A Impossible to substitute

Reason for usage

Portion of usage (Sketch)	Reason for usage
 Cross section of a power diode	Widely used as the passivation film on the surface of P・N junction of power semiconductor devices. The glass material to be used for this purpose needs to satisfy all the following conditions. ①High electrical stability ②Thermal expandability similar to that of silicon ③Calcination temperature is at 1000℃ or below ④High chemical resistance Pb glass is equipped with all the properties from ① to ④ above.

Difficulty for substitution

The main ingredient of Pb glass is PbO and Pb glass also includes Al_2O_3 and SiO_2 etc as well.
This glass does not contain the material to reduce the chemical resistance and it is extremely stable towards various chemicals used in semiconductor processing.
Moreover, the thermal expandability coefficient relatively similar to silicon can be obtained as the thermal expandability coefficient can be adjusted with the composition of Pb O and SiO_2.
The calcination temperature for this is low at 1000℃ or below and does not affect the property of P-N junction.
In terms of reliability, since it can be made into a thick film, it is highly resistant to moisture and its characteristics are stable under high voltage in the range from several hundred V upto 1000 V.

On the other hand non lead-based glass materials include Zn glass, quartz glass and borosilicate glass, etc.
Table 1 shows the comparison of characteristics of these glasses and Pb glass.

1

Type of glass	Electric stability	Thermal expansion coefficient	Calcination temperature	Chemical resistance
Pb glass	○	○	○	○
Zn glass	○	○	○	×
Quartz glass	○	×	×	○
Silicate glass	×	○	×	○

Table 1

Zn, which is the main ingredient of Zn glass has low resistance for etching and the chemical resistance is very low. Figure 1 shows the result of acid treatment of Pb glass and Zn glass. Zn glass is extensively damaged by this treatment though Pb glass is not. Therefore, Zn glass cannot be used.

The thermal expandability coefficient of quartz glass is too small and the calcination temperature is too high to use.

The borosilicate glass cannot be used because the calcination temperature is too high and the alkali ingredient in glass deteriorates the electric characteristic too much.

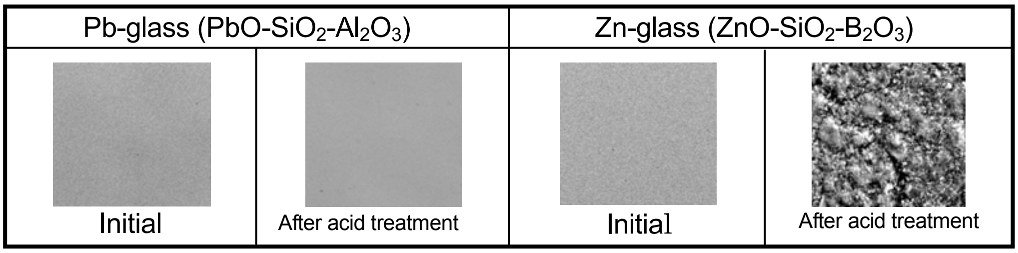


Fig.1 Photo of scanning electron microscope x150
Conditions for acid treatment: Nitric acid (HNO_3) Boiling 3 min.

Due to these reasons, it is impossible to use Pb-free glass as substitution for Pb glass.

Explanation of Technical terms

Technical terms	Explanation
Passivation	Stabilization layer on the surface of semiconductors
Bridge rectifying device Power diode Power thyristor Power transistor	Type of electric semiconductor element
P-N junction	Basic structure of semiconductor elements
Calcination temperature	Temperature to form glass film
Zn glass	Glass mainly composed of ZnO
Quartz glass	Glass mainly composed of SiO_2
Borosilicate glass	Glass mainly composed of SiO_2, B_2O_3 and Na_2O