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# The RoHS Directive

## an answer to your questions

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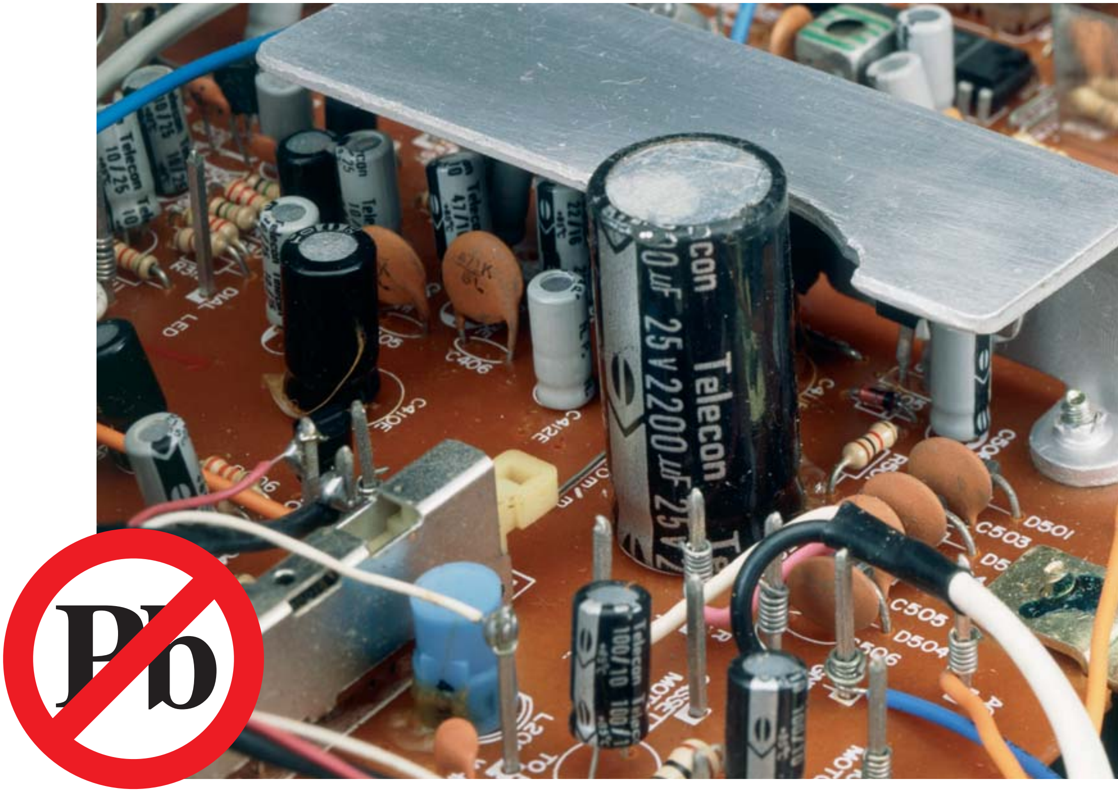


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# preface

*The RoHS Service, a cooperation between SIRRIS and IMEC with the support of IWT, went ahead on 1st July 2005. The aim of this service is to assist companies in implementing the RoHS directive. In the first year of operation over 100 companies contacted the RoHS Service with questions concerning the RoHS directive and its implementation.*

The 'Restriction of Hazardous Substances' or RoHS directive bans Pb, Hg, Cd, hexavalent Cr and the flame retarding families of the PBB and PBDE type from a lot of electrical and electronic products that are put on the European market from 1st July 2006. Because lead is a basic component of the as yet generally used tin-lead solder and no lead-free 'drop-in' replacements exist, the impact of this directive is exceptionally great on the electronic industry and extends over the entire supply chain. Hence, a lot of companies have questions as to both legal and technical matters.
This handbook provides a number of answers to frequently asked questions concerning the RoHS directive. The first part comprises 25 frequently asked questions as to the interpretation of the directive. The second part answers 13 frequently asked questions about the technical reality within the directive.

Our thanks go to the ICT department at Agoria.



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## Interpretation and implementation of the RoHS directive

We have gathered the 25 most frequently asked questions and answers as to the legal aspects of the RoHS directive in this document. It answers important questions like:

- Does our product fall within the scope of RoHS?
- Are there RoHS exemptions applicable to our products?
- Is RoHS applicable to electronic components only or to the whole product?

## 25 FAQ on the legal aspects of the RoHS directive

*The most relevant questions as to the legal side of the RoHS directive have been gathered in this chapter. The questions are answered generically to clarify the principles to be followed. These principles may be applied according to the specific situation of your company and/or your specific products.*

1. Does our product fall within the scope of RoHS?
2. Are there RoHS exemptions applicable to our products?
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legislation: 25 FAQ

13. We have requested RoHS declarations of conformity from our suppliers and requested them to deliver RoHS conforming components. Have we done enough?
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17. What about RoHS outside the EU?
18. I have one of our products here. Can you do some tests and deliver us a certificate of compliance with RoHS?
19. Which tests must I carry out to find out whether my (lead-free) product complies with RoHS?
20. I, an OEM, still have 1000 units of non-RoHS compliant equipment in my warehouse. Can I still sell them? (after 1st July 2006)
21. My distributor still has 1000 units of non-RoHS compliant equipment in his warehouse. Can he still sell them? (after 1st July 2006)
22. Must products I export outside the EU also comply with RoHS?
23. My customer is asking me for a declaration that the part I deliver conforms to RoHS. What is my position? What should I do?
24. Is a RoHS label obligatory? Should RoHS compliance be certified?
25. What should I do to make a non-RoHS compliant product compliant with RoHS?

## 1. Does our product fall within the scope of RoHS?

This is undoubtedly the question asked most frequently to the RoHS Service and, moreover, a question that in many cases cannot be answered very easily. A persistent misunderstanding must certainly be resolved: the RoHS directive is NOT limited to consumer goods. A lot of professional and industrial equipment do fall under the RoHS directive.

Electrical or electronic products that fall under specific environmental directives such as batteries (battery directive 2006/66/EC) fall outside the scope of RoHS and are not considered in more detail here.

In order to be able to answer the above question, three subquestions must be answered:

*Question 1: Is your product a finished product or a part of a larger whole that has been put on the market as a finished product, or is it a part of a fixed installation that is not put on the market as a finished, functional unit?*

- If the product is a part of a larger whole that is placed on the market as a finished product, then no direct RoHS obligations are involved as to this part. This all depends on what kind of product the part will be used for. If it is a product that falls under the RoHS directive, then the part must also comply with RoHS conditions.
  If this is not the case, then other or no restrictions may be applicable.
  As a manufacturer of this part you are bound by the specifications (contractually) imposed by your customer, whether or not related to RoHS restrictions, but you have no direct RoHS obligations.
  You are, after all, not putting any finished product subject to RoHS on the market. In fact, there is no question of a RoHS compliant part, only of a product complying with RoHS, composed of RoHS compatible parts and assembled by means of a RoHS compatible assembly process.
  **The RoHS obligations are consequently only valid for producers/importers of electrical or electronic equipment and only indirectly for manufacturers of parts of this equipment.**
- If the product is a part of a fixed installation, the same is true as above.
  A fixed installation is defined as a combination of different devices, systems, finished products and/or components assembled and/or set up by a professional installer at a specific location to work together in a predefined environment to carry out a specific task and not intended to be put on the market as a single functional or commercial unit.
  **The fixed installation falls outside the scope of RoHS as this does not relate to one of the product categories put on the market as a finished product.**

- The product is only eligible to fall within the scope of RoHS if it is put on the market as a finished product.
  At the moment, clarity is still lacking at a European level as to what is precisely meant by a fixed installation. Further explanation is expected in this regard from the European Commission.

*Justification and marginal notes:*

If the obligation should relate to non-finished products such as parts (e.g. electronic components), then each product containing electronics should by definition be made of RoHS compatible parts, and consequently also products that fall outside the scope of the RoHS directive without discussion, such as cars, airplanes and military equipment. The latter is an explicit exemption.

Moreover, the WEEE directive – to which the RoHS directive refers for the definition of product categories falling within the scope of RoHS – explicitly states in Article 2.1: "This Directive (the WEEE directive) shall apply to electrical and electronic equipment falling under the categories set out in Annex 1 A, provided that the equipment is not part of another type of equipment that does not fall within the scope of this Directive." Unfortunately, the RoHS directive does not contain such a specification. The EU commission explicitly states in its Frequently Asked Questions on p. 5 that the same formulation is valid for the RoHS directive. However, the FAQ list is not a legally binding document.


The discussions have not yet been completed in this regard, in particular relating to components for fixed installations.

The reasoning above, also propagated by Orgalime, is applied to electrical installations in residences and other buildings, whereby all electrical and electronic components such as cables, switches, sockets and fuse boxes, are not subject to RoHS (or to WEEE). Some RoHS enforcement authorities think this is going too far. Prudence is consequently required if your products fall in the category of domestic electrical installation components.

If in doubt concerning the RoHS compliance requirements for your product, it is advisable to check with the enforcement authorities in the member states in which your products are marketed. For Belgium this is the "Federale Overheidsdienst – Volksgezondheid, Veiligheid van de voedselketen en Leefmilieu" [Federal Public Service - Health, Food Chain Safety and Environment], DG Leefmilieu.

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*Question 2: Is your product an electrical or electronic product designed to be used at a voltage below 1,000 V alternating current or 1,500 V direct current?*

It is essential that this relates to the main function of the product that must be dependent on electricity as the primary source of power or is directly dependent on the electrical currents or electromagnetic fields. Without electricity the product cannot fulfil its basic function.

If electricity is only required for supporting or control functions, then this is not an electrical or electronic product, even if the product cannot operate without these functions in practice. To clarify: an electric radiator is an electric device. A heater that operates with fossil fuel with electronic adjustment of the air and fuel supply, however, is not an electrical or electronic product.

*Marginal notes*

Some grey areas still remain. E.g.: an air conditioning unit that uses fossil fuels for heating and electricity for cooling or an electrical product that can be used both below and above 1,000 V alternating current.

*Question 3: Does your product fall under one of the product categories defined in the WEEE directive 1, 2, 3, 4, 5, 6, 7 or 10 or does it relate to luminaires or light bulbs?*

If so, then the product is subject to RoHS.

The difficulty in answering this question lies in the interpretation of the indicative product descriptions as indicated in Annex 1B of the WEEE directive. Consequently, the list is certainly not exhaustive.

The Belgian government has already stated that these indicative descriptions must be interpreted very broadly when related to bringing products within the scope of RoHS. However, it is unclear whether this is also true when it relates to keeping products outside the RoHS scope, specifically with regard to the interpretation of category 8 (medical equipment) and category 9 (measurement and inspection instruments). Hence, prudence is called for.

The exception to category 6 products – Electrical and Electronic tools – "with the exception of large-scale, stationary industrial tools" – requires the necessary attention. This exception to category 6 products is too easily cited to "argue" an industrial machine as outside the scope of RoHS. However, in the description of this exception neither 'large' nor 'industrial' are of major importance, but the stationary character of the equipment is. As stated in the FAQ from the EU this must relate to machines or systems, consisting of a combination of equipment, systems, finished products and/or components, each of which is designed to be used in industry only, permanently fixed and installed by professionals at a given place in an industrial machinery or in an industrial building to perform a specific task. (see also the definition of 'fixed installation'). It is essential that this installation is not intended to be marketed as a single functional or commercial unit. Consequently, an industrial machine that is marketed as a whole and can operate as a functional unit, no matter how large and difficult to move, must comply with RoHS. In this regard the example of the drilling machine as a "large, stationary, industrial installation" given in the Orgalime guide 'A practical Guide to understanding the scope of RoHS and WEEE' on p.25 is incorrect.

If the finished product cannot be categorized into one of the product categories subject to RoHS, it does not have to comply with RoHS. A fixed installation that is not marketed as a functional, finished product by definition falls outside the product categories of RoHS/WEEE and consequently also the parts thereof, unless the part is explicitly mentioned, such as luminaires.

As previously mentioned, the conclusion based on this, that parts of such installations do not have to conform to RoHS, are still under discussion.

In summary, if the product is a finished product for which questions 2 and 3 are affirmative, then the product must comply with RoHS.

## ■ 2. Are there RoHS exemptions applicable to our products?

The reason for this question not being considered under the previous one is that the RoHS exemptions are very different to the product definitions and interpretation required to define the scope. The exemptions describe very specific applications of the prohibited substances that are allowed in all or some product categories subject to RoHS. Consequently, there are no RoHS product exemptions: a product either falls within or outside the scope of RoHS. There are only exemptions as to the use of the prohibited substances for applications for which there are currently no proper technical alternatives. Exemptions – as with a lot of other aspects of the directive – should be considered to be temporary in nature. The directive states that the exemption must be reviewed at least every four years.

In the majority of RoHS compliant products one or more RoHS exemptions will be applied. Just think of the 'lead in ceramic components' exemption. Which electronic product does not contain ceramic resistors or condensators? The majority of exemptions are applied at the component level. Consequently, it must be verified whether the application of the prohibited substances at a component level conforms to the RoHS regulations. The regulation may be product dependent. In this way 'lead in solder' and hexavalent chromium (temporary until 1.7.2007) are permitted for some of the product categories subject to RoHS. A rare exemption is situated at the assembly level of the electronic product: the 'lead in solder' exemption for IT servers and telecommunications infrastructure equipment. The impact of this exemption is great and requires an adapted product design and production strategy if applied. RoHS5 products are sometimes mentioned (RoHS compliant with the exemption of lead in solder) versus the RoHS6 products (RoHS compliant for the 6 prohibited substances).

## 3. Is RoHS applicable to electronic parts alone or to the entire product?

The RoHS limitations on the use of the prohibited substances are valid for the complete, finished product, not only the electronic parts. This consequently also means that mechanical parts, such as casing, frame, bolts and nuts and even the labels stuck to the product must conform to RoHS. All these components must be checked on the presence of prohibited substances. A few tricky issues in relation to RoHS are: Pb and Cd in plastics, Pb in Al and steel parts, Cr6+ finishing on metal components like nuts and bolts, but also on electronic connectors, flame retardants in recycled plastic, etc.

## 4. Our products fall under IT and telecom, category 3 and may use the 'lead in solder' exemption. So we do not need to be concerned about RoHS?

This statement is not true. You even have a lot of RoHS work to do. Firstly, are you certain that your product can claim the 'lead in solder' exemption? This exemption is after all not valid for all IT and telecommunications equipment but only for "servers, storage systems and multiple storage systems, network infrastructure equipment for switches, signal processing, transmission and network management for telecommunications." Hence, you must first verify whether your product falls under this category of products.
The 'lead in solder' exemption is only valid for the use of the solder and the solder finishing used on the component terminals, which become an integral part of the solder in the finished product. For the rest, the product must fully comply with the RoHS directive.
The 'lead in solder' exemption is certainly not a general exemption for the use of lead in IT and telecom equipment. You are only allowed to solder with tin-lead solder. You must draw up a RoHS compatible Bill of Materials for all your products. At a technical level you must ensure that the new RoHS compatible components are metallurgically compatible with the SnPb soldering process. The availability of suitable 'backwards' compatible components will become problematic in the near future.

The application of the 'lead in solder' exemption may be very useful but does not make the RoHS compliance implementation easier. Moreover, the temporary nature of this exemption, based on the lack of sufficient information on the reliability of lead-free solder joints, should not be forgotten.

## 5. How can I find out whether my product falls within the RoHS scope or not?

In the first place you should become familiar with the descriptions of the product categories as described in Annex I of the WEEE directive 2002/96/EC.
Then you can start from the description of the scope in the FAQ from the European Commission. This is regularly being revised and can be downloaded free of charge from the European Commission website: http://ec.europa.eu/environment/waste/weee_index.htm
For additional advice contact the RoHS Service.
If you are an Agoria member you can also contact Filip Geerts, department of Electrical engineering and ICT at Agoria.
The European Court of Justice is solely competent for a legally binding judgment. The European Commission states that it is the task of the producer to establish whether or not a product falls within the scope of RoHS as the producer is the best placed to assess the characteristics of his product.
RoHS enforcement is a national matter: when in doubt you must contact the enforcement authorities of the various member states. In Belgium this is the "Federale Overheidsdienst – Volksgezondheid, Veiligheid van de voedselketen en Leefmilieu" [Federal Public Service - Health, Food Chain Safety and Environment], DG Leefmilieu.
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The RoHS directive is an Article 95 of the EU treaty, which means that the scope of the RoHS directive must be the same in all member states. Practice will indicate to which extent this will effectively be the case.

## 6. How can I obtain a RoHS exemption?

Obtaining an exemption is a long process which is not always successful. The application must be sent to the European Commission. A detailed description of the use of the prohibited substance must be elaborated with an explanation in accordance with Article 5(1) of the RoHS directive of the lack of a valid technical alternative. Cost arguments are not taken into account.
No exemptions are allowed for specific products, only for specific applications of prohibited substances, possibly restricted to certain product categories.
Exemptions borne by multiple companies have the best chance. For that reason it is best to submit applications for exemptions via a professional federation, such as Agoria, as it disposes of a European network.

## 7. Our products are lead-free, then surely they comply with RoHS? Our products comply with RoHS, then surely they are lead-free?

The answer is negative to both questions or at least "not necessarily". A RoHS compliant product and a lead-free product are two completely different things.
A lead-free product does not necessarily comply with RoHS because it may contain other prohibited substances. An example of this is a lead-free product that contains a hexavalent chromium mechanical part. On the other hand, a RoHS compliant product may contain a lot of lead as a result of the many exemptions existing for the use of lead. So do not use a lead-free label just like that for a RoHS compliant product. You might be guilty of misleading advertising! Moreover, it should be noted that a lead-free and/or RoHS compatible component would not necessarily be lead-free solderable. RoHS compatible, lead-free, lead-free solderable are three completely different things. As to RoHS compliance, the 'lead-free' characteristic is in fact irrelevant. Being compatible with the RoHS regulations and lead-free soldering are consequently relevant and the definitions of the two are not the same.

## 8. Must replacement parts conform to RoHS?

As recycling electrical and electronic devices is good for the environment, the RoHS directive is not applicable to second-hand equipment.
Repairing and even upgrading the devices marketed before 1st July 2006 may also be realized with non-RoHS compatible components, insofar as this product is not marketed as new. Products marketed as new products from 1st July 2006 must be repaired with RoHS compatible components.

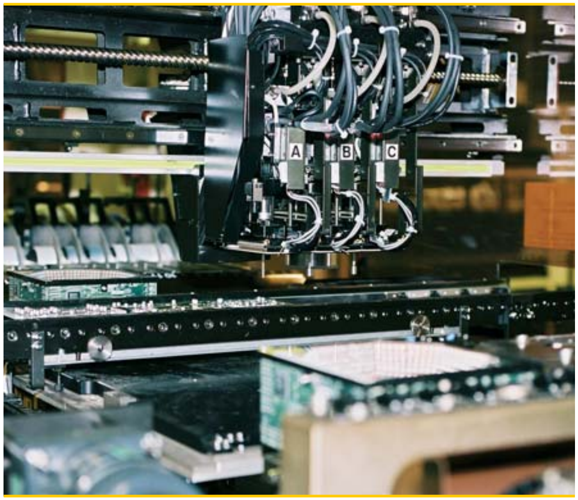
## 9. How must we demonstrate RoHS compliance?

The text of the RoHS directive does not stipulate how RoHS compliance should be demonstrated. No certification or RoHS label is provided. The assumption is that if a product must be RoHS compliant from 1st July 2006, this will be true for all products put on the EU market from 1st July 2006. Of course, the aforementioned does not answer the question of how this will be verified and what must be submitted for a verification.
In order to give an answer that is as uniform as possible throughout the entire EU, the EU RoHS Enforcement Authorities Information Network was established. They published the first edition of the 'RoHS Enforcement Guidance Document' in May 2006. Again, this is only an informative and advisory document without any legally binding force. However, there is a broad consensus among the RoHS Enforcement Authorities – including the Belgian RoHS authority – concerning the principles stipulated in this document so that we can consider this document as a

guideline.
According to this document the RoHS enforcement must be based on three principles:

- A common interpretation across EU member states regarding these products that are considered to fall within the scope of the RoHS directive.
- A presumption that products falling within the scope of RoHS conform to its requirements.
- Self-declaration by producers.

The self-declaration must comprise a RoHS overview documentation and compliance documentation. The overview documentation must specify the RoHS contact within the organization, give relevant company information, describe the RoHS compliance approach applied in the company and ensure an overview of the data quality systems implemented to preserve the correctness and quality of the RoHS relevant data.
Two routes are provided for RoHS compliance.
Route A is a process-oriented route in which RoHS compliance is guaranteed with a 'Compliance Assurance System' or CAS (see also ISO9000). Route B is a product/component-oriented route based on material declarations for the components used. However, this is insufficient. It must also be shown that the necessary actions, such as audits and tests, are and have been carried out to guarantee that the information obtained is reliable. Route B is mainly aimed at SMEs. Large companies are expected to set up a RoHS CAS. (More details about this can be found in the 'RoHS Enforcement Guidance Document'.)
The industry is also active in this field. For setting up a RoHS CAS, reference can be made to the IEC standard IECQ QC 080000: Electrical and Electronic Components and Products Hazardous Substance Process Management System Requirements (HSPM). This describes the embedding of a RoHS CAS in the existing ISO9000-2000 platform. For material declarations, the IPC, the original American but internationally operating Association Connecting Electronics Industries, has formulated a set of standards (IPC-175X: Declaration Process Management Standards), including electronic forms for applying for and providing material declarations for components.
Setting up such a CAS is not an unnecessary luxury, considering the severe penalties related to breaching the RoHS regulations, the dynamic of RoHS matters,



the complexity of the electronic supply chain and other directives such as the EuP (Energy Using Products) and REACH (Restriction, Evaluation, Authorisation of CHemicals). Possible additional declarations of non-RoHS substances may be necessary for these directives. Having an efficient and operational CAS will certainly be a competitive advantage in the future, or even a necessity.

## 10. How will RoHS compliance be verified?

The 'RoHS Enforcement Guidance Document' also enlightens the approach here. The RoHS enforcement authorities do have a lot of options in setting the priority of inspection actions. The Belgian state has indicated that it will give priority to high volume products and products with a high RoHS risk. The latter products include all types of soldered electronic assemblies due to the solder. It is expected that reports of RoHS infringements by third parties (possibly a competitor) could play an important role in the enforcement policy.

A first step of the enforcement is the request for the necessary RoHS compliance documentation for the product. However, it has not been excluded that some RoHS authorities will proceed directly to the application of XRF analyses (X-Ray Fluorescence) to detect prohibited substances.

Note: the detection of lead in an electronic product using an XRF analyser is absolutely no proof of the non-compliance with RoHS for that product due to the many exemptions in relation to the use of Pb. This relates to exemptions that can also be found in the majority of electronic products, such as lead in ceramic components, lead in finishing of compliant pin connectors, lead in flip-chip connections, lead in high melting point solder (>85 per cent lead), lead in solderable finishes of fine pitch components, ... Due to the dimensional resolution and characteristics of the XRF measuring technique, this technique usually does not make it possible to distinguish between permissible and prohibited uses of lead. More advanced techniques are required for this such as SEM-EDX or a chemical analysis.

In case the documentation submitted is not sufficient for the authorities, additional documentation may be requested and sampling may be proceeded to. If a breach is established, the RoHS authority may proceed to enforce penalties and/or demand remedial actions that must be carried out within an agreed period.

## 11. What are the penalties for breaching the RoHS directive?

The enforcement of the RoHS directive is under the jurisdiction of the various EU member states. In some countries breaching the RoHS directive is a criminal act. Fines range from € 500 (Italy), € 1500 (France) to € 50 000 (Germany) per non-compliant product, general fines range from €100 000 (Italy) to

€15 000 000 (Ireland) and even to €22 000 000 (Belgium). Prison terms from 1 to 10 years (in Belgium, Ireland, the Netherlands and Sweden) are possible.
The measures indicate both the severity and variation of the penalties imposed when breaching the nationally implemented RoHS directive. In addition, the seizure of property and profits and publication of the judgment are possible additional penalties.
The Belgian penalty policy is based on the act of 21st December 1998: this is the 'act relating to product standards for the promotion of sustainable production and consumption patterns and for the protection of the environment and public health,' to which the RoHS Royal Decree of 20th October 2004 refers in article 6. This act stipulates that: "Art. 17. § 1. Is penalized with a prison sentence from eight days to three years and a fine of (€160) to (€4 000 000) or with one of the penalties alone (W 2003-03-28/42, art. 11, 003; Effective date: 09-05-2003): 1° a party infringing the regulations stipulated by or pursuant to articles 5, 7, 8 and 9 of this act, when applicable to the prohibited products or substances, preparations or biocides that are classed as hazardous".
The fines stated must be increased by 45 surcharges – factor 4.5, which increase the fines to a minimum of € 720 and a maximum of € 22,000,000.
It is clear that the RoHS directive should not be taken lightly.

## 12. The electronic assembly of our products is carried out by a subcontractor whom we asked to manufacture in compliance with RoHS from 1st July 2006. RoHS compliance is consequently the responsibility of the subcontractor and not our responsibility as OEM?

This statement is certainly incorrect. The Original Equipment Manufacturer (OEM) who markets the product bears full responsibility for the RoHS compliance of the product, even if the name of the OEM company is only stuck on the product by commission. This is also true for importers into the EU of the product, whose name is not even mentioned on the product.
The importer is considered to be the producer on the basis of the RoHS directive. The subcontractor has no legal obligations except to comply with the contractual agreements between customer and supplier and to provide correct, truthful information, which complies with normal business practice. The OEM is responsible for carrying out the necessary formalities to ensure that the subcontractor delivers a product compliant with RoHS.
The simple order "deliver RoHS compliant products" will certainly not be sufficient here. Clear instructions on the soldering materials to be used, the supply of components, the stock management and inspection and evaluation of the logistics and production management methods with the subcontractor are necessary here.

Verify whether the subcontractor is able to produce in compliance with RoHS. Being able to distinguish between RoHS and non-RoHS conforming components, materials and products on the production floor and in the logistical systems is essential but not necessarily obvious.

## 13. We have requested RoHS declarations of conformity from our suppliers and requested them to deliver RoHS conforming components. Have we done enough?

No, this is necessary but not sufficient. As indicated in the 'RoHS Enforcement Guidance Document' you must also be able to show that the certificates provided are reliable and that the components supplied correspond with the certificates.

It is also not sufficient to make the one-off switch to the supply of RoHS compatible components. It should be verified whether the RoHS supply remains in conformity. When components are taken from component brokers this is certainly not guaranteed. The component coding practices of some component manufacturers (no separate codes for RoHS and non-RoHS compatible components or even the reintroduction of the old non-RoHS compatible codes after the RoHS transition) make the control of the RoHS compatibility of components anything but obvious but all the more essential.

In addition to the RoHS compatibility of the components the RoHS compatibility of the Printed Circuit Board must also be verified. Moreover, the electronic assembly may not be forgotten. Verify whether the production is realized in conformity with RoHS. Especially the logistical aspect of the production is complex and requires the necessary attention and verification.

## 14. How much lead can a product complying with RoHS contain? What are the maximum levels of prohibited substances?

The question of the quantity of the lead that a RoHS compliant product may contain cannot be answered in general: 1 kg may be acceptable, 1 ng may be too much. The answer depends on where the lead is located. The limitation refers to the presence of lead (and of other substances prohibited by RoHS), specified as a weight percentage of the HOMOGENOUS MATERIALS present in the product, not as a maximum quantity per product or even per component. The definition of homogenous materials and the maximum concentration of prohibited substances in the homogenous materials is defined in the amendment 2005/618/EC to the RoHS directive. The maximum concentrations are 0.1 percentage of weight for Pb, Hg, Cr6+, PBB, PBDE and 0.01% percentage of weight for Cd for all homogenous materials for which no RoHS exemptions are applicable.

Homogenous materials are defined as materials that cannot be separated mechanically. In practice, the term

'homogenous materials' means materials with uniform physical characteristics, distinguishable from other homogenous materials with their own uniform characteristics. In this way the zinc chromate coating is a homogenous material distinguishable from the substrate (steel or aluminum) on which it is applied.
The Cr6+ restriction is consequently valid for the chromate layer but not for the chromate layer plus the substrate.

## 15. One of the prohibited substances is still used in the production of a component. Can that component be used in a product complying with RoHS?

Yes, as long as this prohibited substance does not exceed the maximum concentration in any of the homogenous materials present in the end product. The RoHS restriction relates to the product, not the production process. In this way the use of hexavalent chromium in chromates is still permitted as long as the end product does not exceed the limit of 0.1 per cent in the homogenous materials. Note that some RoHS enforcement authorities go one step further and in addition to the maximum concentration limits also take into account the aspect 'intentionally added' as an incriminating aspect. A production process that uses one of the prohibited substances may then result in a possible discussion concerning the aspect of intentional addition.

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## 16. My product complies 99 per cent with RoHS. Am I safe? What should I do?

No, you are not safe because your product does not comply with RoHS. A product either complies with RoHS or it does not. There is no grey area or margin, nor is there a method for defining the percentage of RoHS compliance. Such a percentage can only indicate that you have done your best to obtain a RoHS compliant product. Strictly speaking you have not succeeded and you may not market this product.
It is extremely important that there is a documented method available whereby you guarantee the RoHS compliance of your products. The quality of this method

will determine to a significant degree the consequences of a conclusion of non-compliance of your product. 'Due diligence' must be apparent from this. You have taken all the necessary measures to comply with the regulations and to market a RoHS compliant product. It is also worth mentioning that in some countries, like Ireland, there is a reporting obligation for non-RoHS compliance. If you do not report this, you are not only guilty of an infringement of the RoHS regulations by marketing a 99 per cent RoHS compliant product but also of circumventing the reporting obligation.

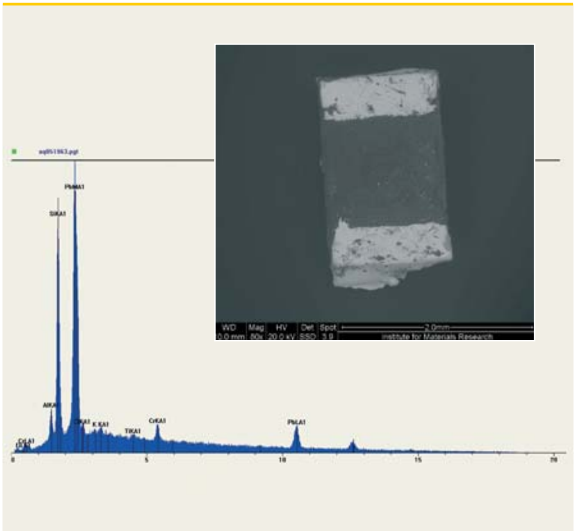
## 17. What about RoHS outside the EU?

RoHS has become a worldwide issue. Various countries outside the EU have introduced comparable RoHS legislation or are in the process of preparing this. This is a very dynamic event, of which the status is changing daily.
A number of EU neighbouring countries like Switzerland and Norway have implemented the EU RoHS regulations.
In the United States, where this environmental matter falls under the jurisdiction of the individual states, California has introduced a RoHS regulation that has become effective since 1st January 2007. However, the Californian RoHS is much more limited in scope than the EU RoHS directive and, for example, does not stipulate any limitations regarding flame retardants. The type of products to which the regulation relates is also much more limited and mainly relates to products with a monitor. Over thirty American states are supposed to be working on comparable RoHS regulations.
The important Chinese regulation similar to the RoHS legislation has become effective since 1st March 2007. There are a lot of similarities with the EU RoHS, but also major differences. A few features of the China RoHS:

- The same six hazardous substances are regulated in electronic products. However, a seventh is added to these: "the substance defined as hazardous by the Chinese government."
- China RoHS is not based on self-declaration. A China RoHS certificate from the Chinese certification organization CCC is required to market products on the Chinese market from 1st March 2007.
- China RoHS does not work with descriptions of product categories, but with an explicit list of products that fall under the regulation. This also includes products that fall outside the scope of the EU RoHS, such as car radios, medical equipment, etc.
- Being effective since 1st March 2007 the hazardous substances stated in China RoHS are not yet prohibited. From that date there is a duty to register. At a later stage restrictions will be imposed on certain products.
- China RoHS does NOT provide for any exemptions.

## 18. I have one of our products here. Can you do some tests and deliver us a certificate of compliance with RoHS?

No, this is not possible. If you have the necessary expertise it is not so difficult to demonstrate that a product does not comply with RoHS. The reverse - proving that a random product does comply with RoHS on the basis of an analysis of the materials - is impossible in practice. This would entail the inspection of all homogenous materials for the presence of the six prohibited components and this with an accuracy level that would make it possible to test at a limit of 0.1 or 0.01 per cent. As even a simple electronic product may contain many thousands of homogenous materials, the time required to carry out this analysis and the cost would be phenomenal. RoHS compliance must be shown on the basis of the RoHS compatibility of the components. Material analyses are useful to carry out inspections in a controlled way on materials at risk, such as the soldering of an electronic assembly, the solderable finish on a component terminal, the coating on a mechanical component, the lead content in plastic, etc. This supports significantly the RoHS compatibility declarations of the components used.



## 19. Which tests must I carry out to find out whether my (lead-free) product complies with RoHS?

The RoHS compliance of a product is guaranteed by a correct RoHS compliant design of the Bill of Materials, correct control of the supply chain and a correct, unequivocal control of the production where correct lead-free materials must be used. The most relevant test is consequently the audit of the product realization chain for its capacity to deliver RoHS compliant products. On request from the government to demonstrate the RoHS compliance of the product, a well-documented and audited product realization chain would be much more convincing than a few fragmentary material analyses of an individual product.

Material tests on a product cannot ever guarantee that the product complies 100% with RoHS. In case of doubt of the compliance with RoHS of a product, it may be useful to carry out a number of tests. Preferably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these are non-destructive and low cost. This certainly excludes quantitative chemical analysis techniques, as is required for establishing for example hexavalent chromium concentration. Methods like the 'Leadcheck' indicator, X-Ray Fluorescence (XRF) and Scanning Electron Microscopy (SEM) may be used to detect lead content in soldering joints, metals and plastics.

Contact the RoHS Service (www.rohsservice.be) for more information about the options.

## 20. I, an OEM, still have 1000 units of non-RoHS compliant equipment in my warehouse. Can I still sell them? (after 1st July 2006)?

As the products were not marketed before 1st July 2006 by placing them in the distribution chain, you cannot sell these products in the EU. You may, however, use them in the EU as replacement parts. You can sell the products outside the EU, taking into account the national legislation of the countries to which you export. A lot of countries have similar RoHS regulations or are in the process of developing them.
In a rare case it is possible to make the products comply with RoHS and still market them on the EU market.

## 21. My distributor still has 1000 units of non-RoHS compliant equipment in his warehouse. Can he still sell them? (after 1st July 2006)?

By transferring your products to your distributor you have placed the products on the market and made these available for purchase by the end customers. If this transfer took place before 1st July 2006 then your distributor may still sell these products without limitation.
However, some countries, like Italy have regulations that deviate from the standard in the EU. For that reason it is important to find out about the national practices in the various member states. In Italy sale

was only possible until 31.10.2006, on condition that the goods were registered before 1st July 2006.

## 22. Must products I export outside the EU also comply with RoHS?

No, the EU RoHS regulations only relate to products put on the EU market. However, you must also take into account that a lot of countries are working on their own RoHS legislation or have already introduced such legislation. Moreover, these regulations may deviate from the EU RoHS regulations. In this way an EU RoHS compliant product cannot be put on the Chinese market from 1.3.2007; nor can other electrical/electronic products on the China RoHS list as these must first be certified.

## 23. My customer is asking me for a declaration that the part I deliver conforms to RoHS. What is my position? What should I do?

You have no direct legal responsibility in relation to the RoHS directive. However, you must ensure that your written declaration is truthful so that you are not guilty of fraud. When drawing up a declaration you must certainly verify that your components effectively conform to the RoHS directive. This will in most cases mean that you must request declarations yourself from your suppliers with regard to the RoHS conformity of the materials, components, etc. supplied to you. Moreover, taking the necessary actions to show the reliability of the information provided is recommended. This is possible by requesting detailed technical information and by carrying out targeted analyses on samples. As RoHS conformity should be guaranteed on the homogenous material level, demonstrating RoHS conformity is a complex matter that entails a certain risk of error. Consequently, it is advisable to implement a proper formulation of the declaration that limits your liability for this RoHS conformity. The IPC 175X standards can help in the formulation of RoHS declarations.
The Orgalime guide 'A practical Guide to understanding the specific obligations of RoHS' also gives a number of recommendations for RoHS conformity declarations.

## 24. Is a RoHS label obligatory? Should RoHS compliance be certified?

The RoHS directive stipulates neither the certification nor the application of a RoHS label. There are a few labels in use. However, you must use these carefully.
The use of a label that indicates RoHS compliance may be considered as misleading advertising. You thereby give the impression that you want to distinguish your products from other products in relation to RoHS compliance, while this relates to a legal obligation to which all products must comply.





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Using a lead-free symbol must also be done with care. A RoHS compliant product is after all in many cases not lead-free at all. The use of a lead-free label on a RoHS compliant product may constitute misleading advertising. Hence, the use of such labels is not recommended on products for end customers. For B2B-products and components labels may be useful to distinguish these products from non-RoHS conforming components and products present in the supply chain. The use of industry standards like JESD97 and IPC-1066 for labeling is recommended here.

## 25. What should I do to make a non-RoHS compliant product compliant with RoHS?

If the product has already been manufactured, the options are limited because a lot of electrical/electronic components must be replaced by RoHS compatible versions. The traditional SnPb solder must also be removed, which is usually not feasible in practice. The transformation of existing products to RoHS compliance is only a realistic option in specific cases.

When it relates to an existing design that must be adapted to the RoHS directive, then the following should be realized (here we only consider the general case, not the 'lead in solder' exemption for some IT and telecom products):

1. The Bill of Materials for the product must be checked completely on RoHS compatibility of the components.
2. Non-RoHS conforming components must be replaced by RoHS conforming versions. Ensure reliable RoHS conformity declarations.
3. Register the changes between the RoHS versions of the components and the non-RoHS versions. This may result in the mandatory re-qualification of the component and even a re-qualification of the product. Sn-whiskering of lead-free, Sn-based solderable finishes on components are in this regard one of the most eye-catching aspects of the RoHS conversion, but not the only aspect!
4. Printed Circuit Boards must also be compatible with RoHS. Usually this means the replacement of the SnPb solderable finish of the PCB by a lead-free version. There are a number of alternatives, each with their advantages and disadvantages. Ensure a RoHS declaration of conformity.
5. Because the Bill of Materials has been made RoHS conforming, this does not mean that it is lead-free solderable. Can all components and the board withstand the higher soldering temperature?
   Verify and replace any unsuitable components and the board with lead-free solderable versions.
6. Instruct your assembly unit (internal or external) with regard to the need for lead-free soldering on the product. Establish permissible alloys and soldering material requirements.
   Specify any additional requirements for maximum soldering temperatures if temperature sensitive components are present.

7. Verify that your assembly unit is able to work RoHS conforming and to solder lead-free, both on a logistical and process-technical level.
8. Lead-free soldering joints have other characteristics than SnPb solder joints. Generally speaking this results in a need for the re-qualification of products.

# technical realization: 13 FAQ

## The technical reality of the RoHS directive

The technical side of the RoHS directive is as important as the legal interpretation. The technical aspects of the directive have a direct impact on the quality and reliability of RoHS compliant products and even on products that fall outside the scope of RoHS as a result of changes made at a component level.

Due to the large impact of the directive on the soldering process, we focus on lead-free and non-lead-free soldering in the second part of these FAQs. A few questions that will be dealt with:

- What are the alternatives for the classical SnPb solder?
- What must I do to switch to lead-free soldering?
- Do lead-free and lead-free soldered components cost more?
- 13 FAQ on the technical reality within the RoHS directive

## 13 FAQ on the technical reality within the RoHS directive

*There are a lot of books and other publications about lead-free and SnPb solder. It is still the subject of a lot of research. Hence, the answers to the questions are more intended as guidance. An in-depth study of the technical issues lies outside the scope of this brochure.*

1. What are the alternatives to traditional SnPb solder?
2. What must be done to switch to lead-free solder?
3. I (OEM) have asked the supplier of my electronic assemblies to use lead-free solder from 1st July 2006. Should I do anything else?
4. My products fall outside the scope of RoHS. I will continue to produce as previously with SnPb and need not take any further action.
5. Can all components be soldered lead-free? Which can, which cannot?
6. Do lead-free and lead-free solderable components cost more?
7. Does lead-free soldering cost more?
8. My components are RoHS compatible. They can consequently be soldered lead-free?

## technical realization: 13 FAQ

9. Should I change anything to the Printed Circuit Board (PCB) of a product to be soldered lead-free?
10. Is a lead-free product as reliable as a SnPb soldered product?
11. Which tests must I do to find out whether my lead-free product meets the quality standards?
12. Which tests must I do to find out whether my lead-free product is reliable?
13. Which design measures should I take to design a good lead-free soldered product?



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## 1. What are the alternatives to traditional SnPb solder?

There are a lot of possible alternative lead-free solder alloys. All these alloys are based on Sn as the active element in the solder, as is the case for the SnPb solder. Sn is the element that forms the inter-metallic chemical bond with the metal of the Printed Circuit Board (PCB), of the component terminal or the wire to be soldered. In most cases the material to be soldered is copper, nickel or the iron-nickel alloy Alloy 42.
Unfortunately, there is no practical 'drop-in' alloy for the generally applied eutectic Sn63Pb37-solder, which has a melting point of 183 °C. The solder alloy must comply with a lot of demands, specifically with regard to the melting point, the soldering characteristics, processability in soldering materials like solder paste and solder wire, metallurgical compatibility, strength, ductility, fatigue resistance, corrosion resistance, toxicity, cost, …
Within the electronic industry a consensus has grown over recent years concerning SnAgCu (SAC) alloy as a generic applicable solder alloy.
The concentration of silver (Ag) is in the range of 0 to 5 per cent, of copper (Cu) in the range of 0 to 0.9 per cent. The eutectic SnAg3Cu0.5 – also called SAC305 – has been put forward as the standard by the IPC - Association Connecting Electronics Industries. For some time this was the SAC alloy with 3.8 or 4 per cent Ag. However, the high Ag level proves to be more costly, but does not contribute much to the characteristics of the solder. Due to the suboptimal combination of characteristics of the SAC305-solder in comparison with the traditional Sn63Pb37-solder various alloys are effectively applied within the group of the SAC alloys.
In this way, due to the cost, 'improved' SnCu-alloys are used, primarily in wave soldering. No or only minimal quantities of the expensive silver are added to the SnCu alloy. SAC alloys with a lower silver content are also used because of their better mechanical characteristics. The disadvantage of these alloys is their higher melting point or their non-eutectic solidification behaviour that is expressed in a solidification trajectory of approx. 10 °C.
Besides the group of SAC alloys there are also a lot of other alloys with interesting characteristics. These are actually used for specific applications. SnAgBi is an interesting alloy but requires that no lead contamination may occur. Lead contamination can negatively influence the mechanical characteristics of the SnAgBi solder. Exotic and expensive alloys were used especially in Japan to lower the soldering temperature, and thereby to be able to lead-free solder components adapted to the traditional temperature requirements of the SnPb solder. SnZn and SnZnBi alloys are also used as cheap alternatives. However, these zinc-based alloys have a few major disadvantages, as a result of which they are not eligible as generic solder alloys.
This all results in a changed situation in comparison to the SnPb age. From now on it is no longer obvious which solder alloy has to be used and the solder alloy must be specified in the product design.

The eutectic SAC305-alloy has a melting point of 217 °C. This is 34°C higher than the eutectic SnPb. As a result, the solder processing temperature must be increased by 20 to 30 °C. This requires an adjustment of the surface mount and other components, as well as the PCBs that are soldered using the reflow-soldering process. Reflow soldering means soldering using soldering paste in a hot air oven. The reflow soldering process is the workhorse of the electronic assembly industry. The increased reflow soldering temperature is the reason for the RoHS directive having such a great impact on the electronic industry. Millions of component types must be adapted to the increased soldering temperatures, as well as all the products that use these components. This is primarily a huge logistical task in addition to a technical challenge.

## 2. What must be done to switch to lead-free solder?

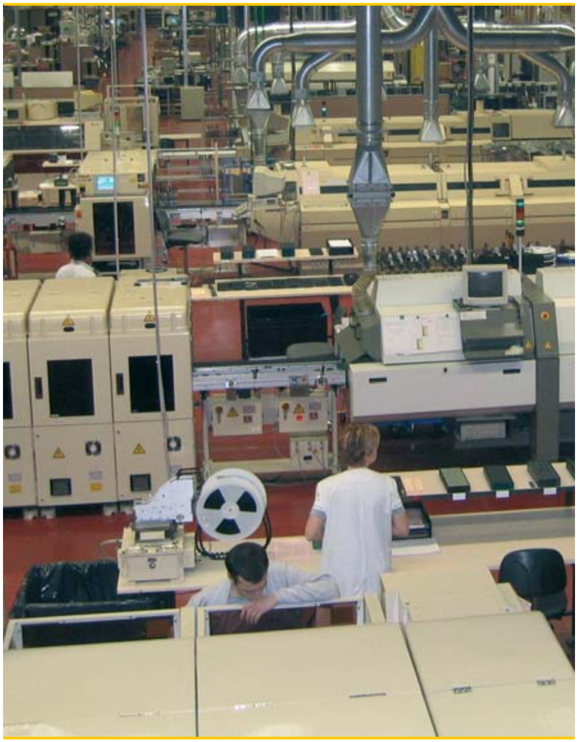
First and foremost you must specify which lead-free solder alloy you want to solder with. In most cases this relates to a solder alloy of the SnAgCu-alloy group. In general, the switch to lead-free SnAgCu-soldering requires an adjustment of the Bill of Materials of the product. The components in the Bill of Materials must be replaced by versions that can withstand the increased soldering temperature.
In cases where no lead-free solder compatible SMD (Surface Mount Device) component versions are available, a switch might be necessary to a through-hole version that can be wave soldered. This requires an adaptation of the PCB design. The alternative to manually solder the SMD component, may, for reasons of costs and primarily quality, only be considered as a temporary solution for small volumes.
Products that must comply with high standards of quality and reliability require further analysis and adaptation. The mechanical characteristics of the SAC solder differ from those of the SnPb solder. This may result in component-PCB combinations that are no longer acceptable for soldering with SAC due to the unfavourable thermo-mechanical load of the solder joint. Solder joints that are subjected to shock must be additionally secured because SAC is much less shock resistant than SnPb.
The PCB is also negatively influenced by the increased soldering temperatures. Especially thicker (1.6 mm and more) and multi-layer cards (six or more) require the use of thermally enhanced laminate materials.
In addition to the thermal requirements there are also metallurgical aspects on which components and PCB must be screened. In order to keep component terminals and PCB soldering areas solderable, a thin solderable layer is applied to the copper or Alloy 42 to be soldered. There are many options for this. One of the most common until now was SnPb solder with a lead content between 3 and 10 per cent. Nothing solders as well as solder itself. In the majority of cases eutectic SnPb solder was used as the finish on the PCB. Apart from the exemption for some IT products and specific applications (fine-pitch components,

compliant pin connectors) the RoHS directive in practice no longer allows the use of these SnPb-based finishes. Even if it is allowed on the basis of the RoHS directive to use SnPb as a finish, it is greatly recommended to avoid the combination of lead-free solder and a SnPb finish. In a number of cases this may result in weaker solder joints. The combination of SnPb soldering balls of the Ball Grid Array BGA-type components and lead-free solder is generally unacceptable and should only be considered in very exceptional cases.

The lead-free solder finishes also result in a number of problems. Pure Sn is sensitive to Sn-whisker formation, that may cause short circuits. NiAu may result in gold embrittlement, 'black pad' phenomena, "skip-plating" and phosphor-related interface weakening. The phenomenon of the creation of a porous layer on the interface between the SAC solder and the soldered Cu-substrate was also observed in some cases. To further elaborate on this would take us beyond the scope of this document. In any case, it is important to evaluate the solder finishes critically for high reliability products.

As the switch to lead-free solder means a significant change in the materials and the components used, the solder joint characteristics and the assembly conditions, the switch to lead-free soldering generally entails the need to re-qualify and thoroughly test the electronic assembly.

In addition to the aspects of product design and qualification, the switch must be planned carefully. The entire supply chain must be aligned in order to ensure that products are switched to lead-free soldering at the right time with the correct Bill of Materials.



## 3. I (OEM) have asked the supplier of my electronic assemblies to use lead-free solder from 1st July 2006. Should I do anything else?

As the reply to the previous question shows, there is still a lot of work to be done. Only in a few exceptional cases – e.g. simple products that only use TH components with the correct solder finish – can be switched to lead-free soldering without any adaptations of the design or Bill of Materials. The switch to lead-free soldering is not only a concern for the assembly department or contractor but also to a great extent a tough job for the design department and the purchasing and planning departments. For details on the switch to lead-free soldering reference is made to the answer to the question: "What must be done to switch to lead-free soldering?".

## 4. My products fall outside the scope of RoHS. I will continue to produce as previously with SnPb and need not take any further action?

This statement is incorrect. The RoHS directive also has an impact on electronic products that fall outside the scope of RoHS. Component manufacturers are switching their production en masse to RoHS conforming components. This usually means the replacement of a lead-containing soldering finish with a lead-free finish, which in many cases means the use of pure Sn, in the Far East also of SnBi. In addition, the plastics of the packaging are adapted to the increased soldering temperatures. As it is not economically justifiable to produce multiple types of components when the market becomes too small, the availability of the old component types used in products not subject to RoHS shall be threatened in a relatively short period of time. The replacement of the SnPb solder finish mainly constitutes a problem for non-RoHS products. The risk of Sn-whisker formation arises and that hazards the reliability. The incompatibility of SnBi with SnPb, through the creation of SnPbBi phase with a melting point below 100 °C also leads to reliability risks. The change of the packaging materials used in the new RoHS and lead-free solder compatible components may require a re-qualification for some applications.
In addition to the availability of SnPb finished components the availability of SnPb-based assembly capacity at an acceptable cost will also be a problem in the long term.
As lead-free soldering with SnAgCu is becoming the new standard, a lot of non-RoHS products will be forced on economical grounds to switch to lead-free soldering.



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## 5. Can all components be soldered lead-free? Which can, which cannot?

No, not all components can be soldered lead-free. At least not in an economically justified, high quality and reliable way. The problems relate to the temperature compatibility with the increased soldering temperature or the metallurgy used on the component terminals.
The following component types have problems with temperature compatibility:

- All 'old' types of non-hermetic (plastic) packed active components. These comply with the J-STD-20 standard and are qualified for a maximum (reflow) soldering temperature of 235 °C for the smaller types, 220 °C for the larger types and the Ball Grid Array (BGA) components. This is inadequate for SAC lead-free soldering.
- For the passive components there is little standardization in relation to the soldering temperature conditions.
  Various component types may lead to problems:
  - Polymer film condensators
  - Aluminum condensators (ELCO)
  - Tantalum condensators
  - Plastic casings for connectors
  - LEDs (discolouration)
  - Crystal oscillators
  - …

Passive components must consequently also be screened thoroughly for their temperature compatibility. Conforming to RoHS and/or being lead-free is absolutely no guarantee of being lead-free solderable. Components that conform to the lead-free solder qualification requirements of J-STD-20C or subsequent versions can be lead-free soldered with respect to the thermal requirements.
At a metallurgical level, the following must be taken into account:

- Ball Grid Array components have solder balls as terminals spread over the bottom of the components. These solder balls must be made of the same material as the solder used. Limited concentration differences of the alloy elements are acceptable. This means the use of SnPb solder balls for SnPb soldering, SAC balls for SAC soldering. Deviating from this may in general lead to severe quality and reliability problems.
- Generally speaking, the use of SnPb soldering finishes must be avoided with lead-free soldering. With the elements tin and silver, lead can form the $Sn_{62}Pb_{36}Ag_2$ phase, with a melting point of 179 °C, which is significantly lower than the melting point of 217 °C of the SAC alloy. The presence of Pb in a SAC alloy entails the risk of local weakening of the solder joint.
- A lead-free solderable finish already used for a long time is a nickel (Ni) layer on which a thin layer of gold (Au) is deposited. Already during the SnPb age a number of problems with this finish were known. If the gold is too thick, this can result in the formation of extremely brittle SnAu inter-metallic regions in the solder, which results in embrittlement of the solder joint. This is the reason, for example, that no Au-

finish is permitted in military products. Due to the risk of Au embrittlement, Immersion Au on Electroless Ni (ENIG) is primarily used for solder applications. This technology then again has the disadvantage of requiring high concentrations of phosphor (P) in the Ni, which may give rise to a weak interface between the Ni and the solder. Due to the higher concentration of Sn and the higher strength of the SAC alloy these problems occur more frequently when soldering with SAC. Prudence is consequently advised in the use of NiAu in high reliability products.

## 6. Do lead-free and lead-free solderable components cost more?

The intrinsic cost of lead-free, lead-free soldering and RoHS conforming components is higher than that of the original components for the following reasons:

- The development costs for new component versions.
- The qualification costs of the new component versions.
- The higher material costs of the solderable finish. Almost all lead-free solder finishes are more expensive than the original SnPb finish. The added cost is limited for the switch to pure Sn or SnBi. The switch to NiPdAu means a significantly higher material cost.
- The cost of the production switchover: engineering, investments and implementation.
- The higher material costs due to the use of higher quality plastics for the packaging. As the component purchasers are not readily prepared to accept an added cost and the component market is very competitive, this added cost is often not calculated in the price of components. Finally, someone will have to bear this additional cost. It is doubtful whether the component suppliers with their small margins are willing to accept this fully.

## 7. Does lead-free soldering cost more?

Of course. The lead-free SAC solder alloy costs no less than a factor 2 to 3 more than the SnPb solder. This is not only due to using the expensive silver but also because of the tin content being 50 per cent higher in the solder alloy, which replaces the much cheaper lead to a great extent. For soldering bars this gives a one-to-one increase in cost. The cost of filling a wave soldering machine and the material costs of this process has consequently greatly increased. For this reason there is significant interest in the somewhat cheaper alloys of the SnCu type especially for these processes. For other processes, soldering materials like solder wire and solder pastes are used. For these soldering materials the alloy is only one of the cost elements. The impact on the solder material cost of the alloy is lower as a result.
The added cost due to the solder alloy, for example for a solder paste, amounts to about 10 to 20 per cent.
In addition to the higher material costs there is also the


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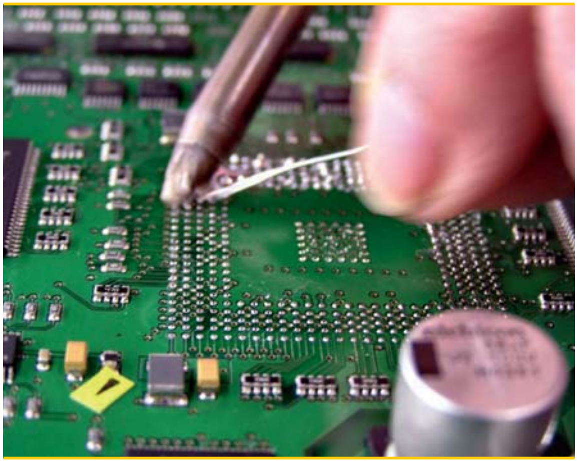
increased energy consumption resulting from the higher soldering temperatures. This is significant in reflow soldering. An increase in the soldering processing temperature by 20 to 30 °C means an increase in energy consumption of about 20 to 40 per cent.
Lead-free soldering leads to a reduction of the processing window at a higher temperature. This has a negative effect on the production yield, with more faulty products and higher repair costs as a result.
These intrinsic higher costs must be borne by someone. Electronic assembly plants work with very small margins. The additional cost cannot be borne solely by these plants. Therefore, an increase of the assembly price is necessary.



## 8. My components are RoHS compatible. They can consequently be soldered lead-free?

This statement is incorrect. RoHS compatible – not containing the prohibited substances – and lead-free solderable are two completely different matters. The removal of the prohibited substances from components to make them usable for RoHS compliant products does not make it possible to solder these components lead-free.
The higher soldering temperature requires drastic measures apart from making the component compatible with RoHS to give the component the increased thermal load resistance, required for lead-free soldering. RoHS compatibility and lead-free soldering ability are two characteristics of components to be evaluated separately.

## 9. Should I change anything to the Printed Circuit Board (PCB) of a product to be soldered lead-free?

This aspect must certainly be evaluated. The layout of the PCB may need to be changed if no lead-free compatible alternative with the same solder pad configuration for a specific component is available. Except for simple electronic assemblies the use of thermally improved laminates is also recommended because of the higher thermal load when soldering. This higher thermal load may lead, for example with the standard FR4 PCB laminates, to via-cracking,

delamination, the creation of Conductive Anodic Filaments (CAF), warpage and discolouration. There are various alternatives with different levels of performance and, obviously, cost. Important characteristics of the laminates relevant in this framework include: the decomposition temperature, the time to delaminate, the thermal expansion coefficient perpendicular to the board surface, the 'curing' mechanism and the glass transition temperature. Finally, the solderable finish must also be lead-free. The widely used eutectic SnPb finish, applied using the Hot Air Solder Leveling (HASL) process, must be replaced by a lead-free alternative. There are various options, each with advantages and disadvantages: lead-free SnCu HASL, immersion Sn, immersion Ag, immersion Au on electroless Ni (ENIG) and organic passivation (OSP) are the most important. All these solutions solder less well than SnPb HASL, even though the SnPb solder ability is almost achieved by some types.
For more information about PCB alternatives, contact the RoHS Service (www.rohsservice.be).

## 10. Is a lead-free product as reliable as a SnPb soldered product?

The reliability of a lead-free product primarily depends on the working conditions to which the product is subjected and the build-up of the product.
As the mechanical and fatigue characteristics of the lead-free solder differ from those of SnPb, the reliability of a lead-free soldered product will, by definition, be different from that of a SnPb soldered product. It could be better, but also worse, depending on the factors previously mentioned.
In the further discussion we have limited the scope to SAC (SnAgCu) soldered products. In general, the higher melting point of the SAC alloy, with the resulting increased soldering temperature, has a negative impact on the reliability of the lead-free soldered product. The higher thermal load to the components and PCB during the production process accelerates the degradation mechanisms and increases the likelihood of damage to these components.
A correct selection – and if necessary correct qualification – of components and PCB minimizes the negative impact of higher thermal load on the reliability of the lead-free soldered product.
With regard to the characteristics and reliability of the solder joint, the story is a little more complex. The SnAgCu is a stiffer, stronger and less plastically deformable alloy than SnPb. This entails that the same level of deformation of the solder joint – e.g. imposed by a difference in thermal expansion between the component and the PCB – causes a much higher mechanical stress level in a SAC solder than in a SnPb solder. Moreover, the higher melting point of the SAC alloy results in an additional stress component if there is a difference in thermal expansion coefficient between the component and the PCB.
This increased mechanical stress must not only be borne by the solder joint, but also by the elements connected by the soldering: the (brittle) inter-metallic layer, the solder pad, the component terminal, the



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interface of the pad or terminal with the board or component body, … All these elements are now, depending on the construction of the product, exposed to significant higher mechanical loads than in the SnPb age. Where the solder joints previously were the weakest spot and failed first or deformed strongly (as a result of which the stress on the surrounding elements remained limited), this is no longer the case. Consequently, an increasing amount of failures of the inter-metallic layer or in the elements adjoining the solder joint is observed. Actually, the interface reliability of lead-free solder balls in the production of lead-free Ball Grid Array (BGA) packaging is a serious problem.
The SAC solder joint is more resistant to fatigue than SnPb when the mechanical load is low, which is usually the case. With high mechanical loads the fatigue resistance is not as good as SnPb.
SAC soldering is also significantly less resistant to shock than SnPb, e.g. if the product falls. The same is true for strong vibrations. All this may be linked to the lower ductility of SAC solder compared to SnPb. By reducing the Ag content, an attempt is made in those applications where the high rigidity and strength of the SAC alloy causes serious problems (e.g. for BGAs) to obtain an alloy with more optimal characteristics.
A lot of the characteristics of the SAC alloy are still not or insufficiently known. At this moment we do not know the acceleration factors required to extrapolate the results of the solder fatigue tests to the working conditions of a product. Consequently, we cannot make life time predictions for a lead-free product. This forms the basis for the 'lead in solder' exemption for some IT and telecom equipment. Establishing the acceleration factors is consequently also the subject of scientific research. All this makes that for products that are subjected to high reliability requirements the aspect of reliability must be approached with the necessary care and prudence. As a general rule it may be stated that configurations that lead to large thermal expansion differences – e.g. a large ceramic passive SMD component soldered on an FR4-substrate – must be avoided.

## 11. Which tests must I do to find out whether my lead-free product meets the quality standards?

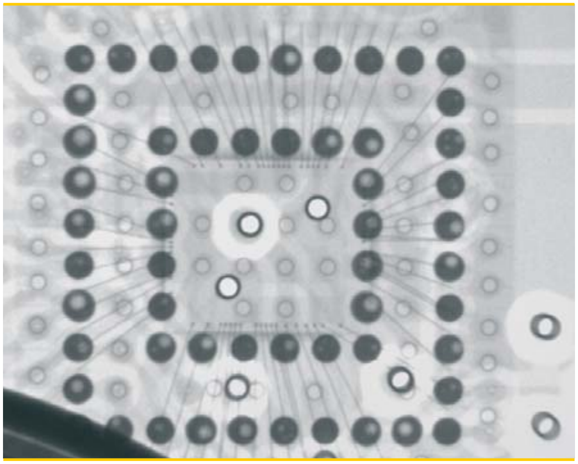
When answering this question we will limit ourselves to the quality of the Printed Board Assembly (PBA) product on leaving production. The quality aspect 'intrinsic reliability in the long term' is the subject of a separate question. The following evaluations are relevant to the quality control of a lead-free soldered product:

- The PBA must comply with the industry standards for PBA acceptance. The most commonly used standard for this is IPC-A-610D (or later versions) Acceptability of Electronic Assemblies. An IPC-A-610D-audit should preferably be carried out by an IPC-certified auditor.
- The lead-free product should be subjected to the required production fault detection tests and functional tests as implemented in the assembly unit

and if applicable supplemented with additional product tests, if the test coverage is insufficient.

- A transmission X-ray analysis gives a good view of the quality of the solder joints but also of the entire quality of the product. It is an important supplement with (and partly a component of) the IPC-A-610D-audit. It may replace this and is consequently recommended.

However, testing alone is never sufficient to guarantee the quality, as 100 per cent testing coverage is not possible in practice. A good Design-for-Manufacturing practice, good quality components and PCB, among other things with respect to the solderability (which is not obvious!), and good assembly instructions, especially regarding the selection of soldering materials, are fundamentally important to obtain a quality product.



## 12. Which tests must I do to find out whether my lead-free product is reliable?

This is an obvious but extremely difficult question to answer. There are no generic tests that can answer this question easily. In addition, even the most extensive battery of reliability tests cannot offer sufficient guarantees without the necessary attention being paid to aspects of 'Design-for-Reliability'. For a product subject to high reliability requirements a combination of a correct 'Design-for-Reliability' practice and a well thought-out testing strategy are recommended. In order to ensure that reliability tests provide relevant and usable results, the testing conditions must be very similar to the conditions to which the product will be subjected. As an alternative and if the necessary technical-scientific support is present, accelerated testing conditions may be linked to the working conditions of the product via acceleration factors. The first type of tests are suitable for testing a product on the short, high load conditions that the product must be able to withstand. Hence, it may not be subjected to this for long. Examples include drop tests, thermal shock, transport tests, etc. However, the greatest difficulty is to evaluate the resistance to long, relative low load conditions that the product will have to withstand for the entire predefined life span (a few to tens of years). As these tests are intended to evaluate the entire life span of the product, a high test acceleration factor is necessary. A sufficiently accurate definition of this



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acceleration factor is an especially difficult and laborious task. To this day we still do not know the acceleration factors for testing SnAgCu-lead-free solder joints for fatigue failure with sufficient precision. The acceleration factor depends on the failure mechanism, the testing conditions and the working conditions. In an average electronic product an uncountable number of possible failure mechanisms is present, each with its own acceleration factor and its own set of optimal testing conditions. Therefore, it is impossible to cover all possible failure mechanisms with a limited set of accelerated tests. In practice, only a limited number of mechanisms are critical for the life span of the product if the correct 'Design-for-Reliability' practice is applied.

The real art is then to identify precisely those mechanisms that are critical and to carry out targeted tests on these to identify the impact on the life span.

Considering the complexity of the reliability evaluation a 'Divide and Conquer' strategy is recommended. Each component of the assembly (components, PCB, mechanics) - including things like the soldering materials used - must each in itself conform to carefully selected specifications and be tested correctly for this before being used in the product. Specifying component requirements is an essential aspect of a good 'Design-for-Reliability' practice. Product tests can then target the evaluation of the assembly. Specifically in relation to the lead-free product, it must be taken into account that generally the failure mechanisms present in a SnPb soldered product are still there but that the critical values are different and consequently also the mutual ratios. In this way, a number of failure mechanisms will occur at a reduced rate in lead-free solder. For example at low mechanical loads SAC has a higher fatigue resistance than SnPb. On the other hand, other failure mechanisms are accentuated. The higher soldering temperature, for example, more easily results in Conductive Anodic Filament (CAF) development in the FR4-material of PCBs. In addition, new failure mechanisms are added, e.g. the Sn-whiskering issue. This determines the type of life span tests that need to be selected.

A good qualification procedure consists of defining a relevant set of operational environmental tests that evaluate the range of high load conditions for the product, supplemented by a set of life span tests based on failure mechanisms. The latter must often be carried out on specifically designed testing structures, not on the end product.

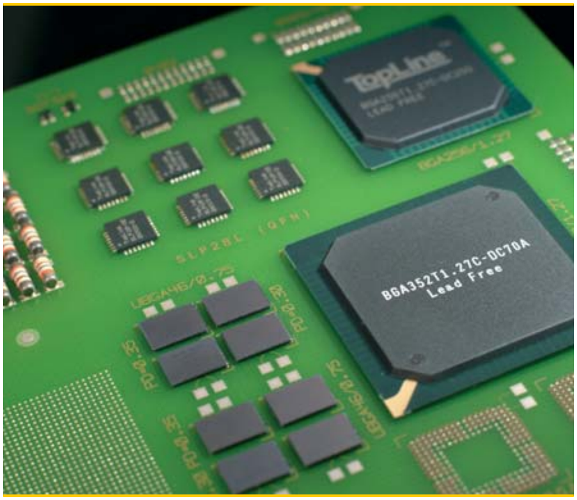
This must be supported by a good 'Design for-Reliability'-practice. It is obvious that this approach requires thorough knowledge of the physics of the electronic product.

## 13. Which design measures should I take to design a good lead-free soldered product?

A good design of a lead-free soldered product requires a basic knowledge of the lead-free soldering processes

that will be used for the assembly of the product. Metallurgical knowledge of the solder to be used and the surfaces to be soldered is also a requirement for arriving at effective 'Design-for-Reliability' rules that guarantee the reliability of the product. This knowledge combined with the product requirements may subsequently be translated into concrete design rules.
The two clearly distinguishable matters of 'Design-for-RoHS' and 'Design-for-Lead-free soldering' are primarily a Bill of Materials design activity. Soldering pad dimensions and mutual distances on the PCB used with SnPb soldering can still be used. Primarily, it must be established which components may be used and which not. The selection criteria are based on the RoHS compatibility of the component, the temperature resistance in relation to the solder joints, the terminal metallurgy of the component and the thermo-mechanical load on the soldering joints. The selection criteria depend on the product specifications, the product application, the intended life span of the product and the priority setting by the producer. In addition, the specifications of the PCB must be defined. More and more detailed instructions are also required for the assembly compared to the SnPb age. Because there are more variables – for example, now there is a choice of soldering alloys – whereas the processing window has become significantly smaller and this at a higher processing temperature, i.e. under more critical conditions.

A detailed discussion of the design rules and PCB/PBA specifications falls outside the scope of these FAQ. For more information please contact the RoHS Service: www.rohsservice.be.



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The texts of these legal articles can be consulted at www.rohsservice.be

## Legislation

RoHS directive (Restriction of Hazardous Substances) 2002/95/EC concerning the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Amendments:

- Maximum concentrations of hazardous substances Commission Decision 2005/618/EC establishing the maximum concentration values for certain hazardous substances in EEE.
- Corrections to the RoHS directive Commission Decision 2005/717/EC amending for the purpose of adapting to the technical progress the Annex to Directive 2002/95/EC.
- Publication of exceptions 11 to 15. Commission Decision 2005/747/EC amending for the purpose of adapting to the technical progress the Annex to Directive 2002/95/EC.
- Publication of exceptions 16 to 20. Commission Decision 2006/310/EC amending for the purpose of adapting to the technical progress the Annex to Directive 2002/95/EC as regards exemptions for applications of lead.
- Publication of exceptions 21 to 27 Commission Decision 2006/691/EC amending for the purpose of adapting to technical progress the Annex to Directive 2002/95/EC as regards exemptions for applications of lead and cadmium.
- Publication of exception 28 Commission Decision 2006/692/EC amending for the purpose of adapting to technical progress the Annex to Directive 2002/95/EC as regards exemptions for applications of hexavalent chromium.
- Publication of exception 29 Commission Decision 2006/690/EC amending for the purpose of adapting to technical progress the Annex to Directive 2002/95/EC as regards exemptions for applications of lead in crystal glass.
- The Belgian penalty policy in relation to RoHS is based on the act of 21st December 1998, the 'act relating to the product standards for the promotion of sustainable production and consumption patterns and for the protection of the environment and public health', to which the Royal Decree of 20th October 2004 refers in article 6.
- WEEE directive (Waste Electrical and Electronic Equipment) 2002/96/EC contains the definition of production categories.

## Non-EU RoHS legislation

- California:
  - California's restriction on the Use of Certain Hazardous Substances in Some Electronic Devices
- Electronic Waste from California's Department of Toxic Substances Control.

- China:
  - Administrative Measures on the Control of Pollution Caused by Electronic Information Products.
  - Management Methods for controlling Pollution by Electronic Information Products – Ministry of Information Industry Order #39.
  - Electronic Information Products Classification and Explanations.

These documents are unofficial translations from Chinese and are consequently only for information purposes.

## Implementation guides (not legally binding)

- Frequently Asked Questions with regard to RoHS and WEEE (source: European Commission).
- Orgalime guide 'A practical Guide to understanding the specific obligations of RoHS': aanbevelingen voor RoHSconformiteitsverklaringen (source: Orgalime – European Engineering Industries Association).
- RoHS Enforcement Guidance Document (source: EU RoHS Enforcement Authorities Informal Network).

## Standardization organizations

- IPC: originally American, internationally operating Association Connecting Electronics Industries (www.icp.org).
- JEDEC Solid State Technology Association: the original Joint Electron Device Engineering Council is the standardization body for the semiconductor producing industry (www.jedec.org).
- IEC: International Electrotechnical Commission (www.iec.ch).

## Relevant standards regarding RoHS/ lead-free soldering

- IECQ QC 080000: Electrical and Electronic Components and Products Hazardous Substance Process Management System Requirements (HSPM). This describes embedding a RoHS CAS in the existing ISO 9000-2000 platform.
- IPC-610D: Acceptability of Printed Board Assemblies.
- IPC 1066: Marking, Symbols and Labels for Identification of Lead-Free and Other Reportable Materials in Lead-Free Assemblies, Components and Devices.
- IPC-175X: Declaration Process Management standards.
- IPC-9503: Moisture Sensitivity Classification for Non-IC Components.
- IPC-9701: Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments.





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- JIG-101: Material Composition Declaration for Electronic Products.
- JESD 97: Marking, Symbols, and Labels of Lead (Pb) Free Assemblies, Components, and Devices.
- J-STD-020C: IPC/JEDEC Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Device.
- J-STD-033B: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices.
- JP002: JEDEC/IPC Current Tin Whiskers Theory and Mitigation Practices Guideline.
- JESD201: Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes.
- JESD22A121.01: Test Method for Measuring Whisker Growth on Tin and Tin Alloy Surface Finishes.

## RoHS service

**RoHS Service** is a non-commercial service with the aim of supporting companies in the implementation of the **European RoHS directive 2002/95/EC**.
The RoHS Service can carry out industry specific studies and projects. The execution is realized by SIRRIS or IMEC experts, if necessary supplemented by the expertise of third parties. Price-setting is realized on the basis of a tender after notification of the company request.
The RoHS Service intends to offer the fullest support possible.

- Interpretation of the directive.
- Lead-free soldering
- Component and card specifications
- Product specific design problems
- Quality specifications and test procedures
- Definition, selection and evaluation of machines
- Solder alloys and solder materials
- Processing problems, processing inspection and quality
- Logistical organization
- After Sales Service
- Alternatives for hexavalent chromium


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