7th Adaptation to scientific and technical progress of exemptions 8(e), 8(f), 8(g), 8(h), 8(j) and 10(d) of Annex II to Directive 2000/53/EC (ELV)

Consultation Questionnaire Exemption No. 8(f)

Review of Exemption 8(f) “Lead in compliant pin connector systems”

Input of the automotive industry expert group, represented by ACEA, JAMA, KAMA, CLEPA, et al.

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

The above mentioned industry stakeholders request continuation of the exemption.

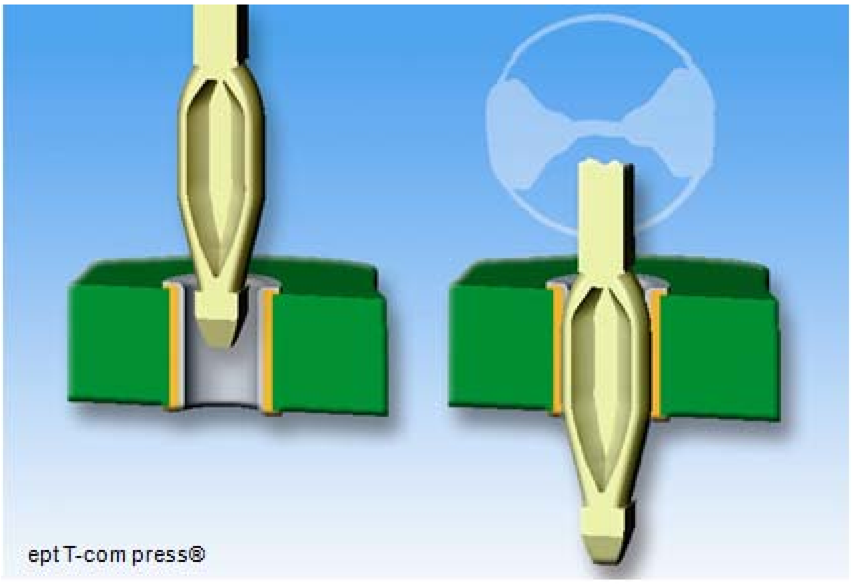
Questions & Answers

1. Please explain the status of lead-free CoPiCS for use in automotive applications.

Within the first questions the first parts should help non- experts to get some rough understanding about CoPiCS. Some parts are taken from Oeko et al. 2010. In order to facilitate reading a citation is not made after each individual sentence.

<u>Introduction:</u>
Compliant pin connector or press-fit connectors systems provide a method of attachment and electrical contact between a connector and printed circuit board (PCB) which does not require a soldering operation. The pin contacts are inserted into plated through holes (PTH) in the PCB (see figure 1) and the mechanical design of the pin provides reliable electrical contact (Oeko et al. 2010). The compliant pins must be sufficiently flexible to deform as they are inserted into the holes without an excessively high force that might damage the plating in the holes (Gensch et al. 2009) (Oeko et al. 2010). The press fit technology thus saves solder material and energy (ACEA et al. 2009f).

CoPiCS are widely used in safety-related parts like anti-lock braking systems or airbag systems. In case of a failure human life is directly endangered.



<u>Figure 1</u>: assembly of a press fit pin connector into a board structure

<u>Soldering vs. CoPiCS</u>
Technologically, pin compliant connectors avoid the difficulties encountered in soldering a large number of closely spaced pins. The total thermal mass can be so large that it is difficult to achieve the correct temperature throughout the connector for the solder to flow and wet the surfaces. The situation is even more difficult with lead-free solders due to their slower wetting and higher assembly temperature. As solder is not used, smaller pads can be used around each pin, so that they can be placed closer together (Gensch et al. 2009) (Oeko et al. 2010). The thermal situation will be even more critical because of the miniaturization of pins and components. Miniaturization is needed because of performance and resource issues. Further on high-current application which do have a lot of copper on the PCB and on the contact element will have difficulties to be soldered. The additional copper will make it even more difficult to reach the needed temperatures. Result will be bad hole filling and connectivity and wettability problems.

<u>Function of lead in CoPiCS</u>

The tin-lead plating on the pins contains about 5%-10% lead and is only about 0.25-1.5 microns thick. Tin-lead plating covers only the termination portion of the contact, which includes the compliant section (about 2-7 mm length). Such connectors are used on printed circuit board assemblies contained in most automotive applications (Kadesch 2001) (Oeko et al. 2010).

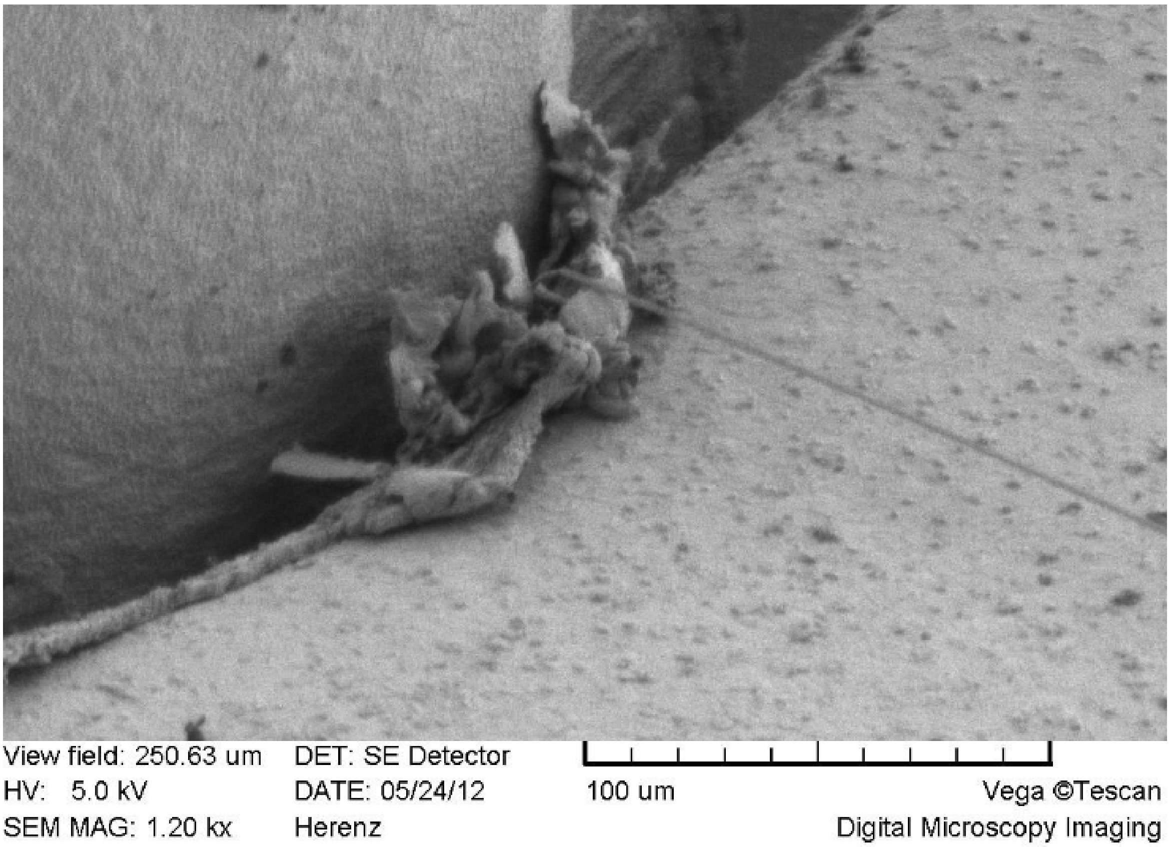
Tin-lead plating is required to

- provide lubrication while the pins are inserted in order to reduce the insertion force; thus reducing damage of the PTH which ensures the required reliability of the contact.
- ensure good electrical contact once the pin has been inserted;
- prevent whisker growth (Oeko et al. 2010).

ACEA et al. (2009f) state that lead is necessary to avoid whisker growth. Whisker problems appear if lead-free chemical tin finish on the PCB and galvanized tin surfaces on the press-fit pins are combined together (see examples in figures 2 and 3). The probability of whisker growth increases by (ACEA et al. 2009f)

- large deformation in the entrance area of the press-fit zone;
- tin abrasion from the pin surface, adhering at the PCB-bushing surface (Oeko et al. 2010).

Unfortunately whisker growth is not fully understood until now.



<u>Figure 2</u>: whisker formation ("line" in the right part of the picture)

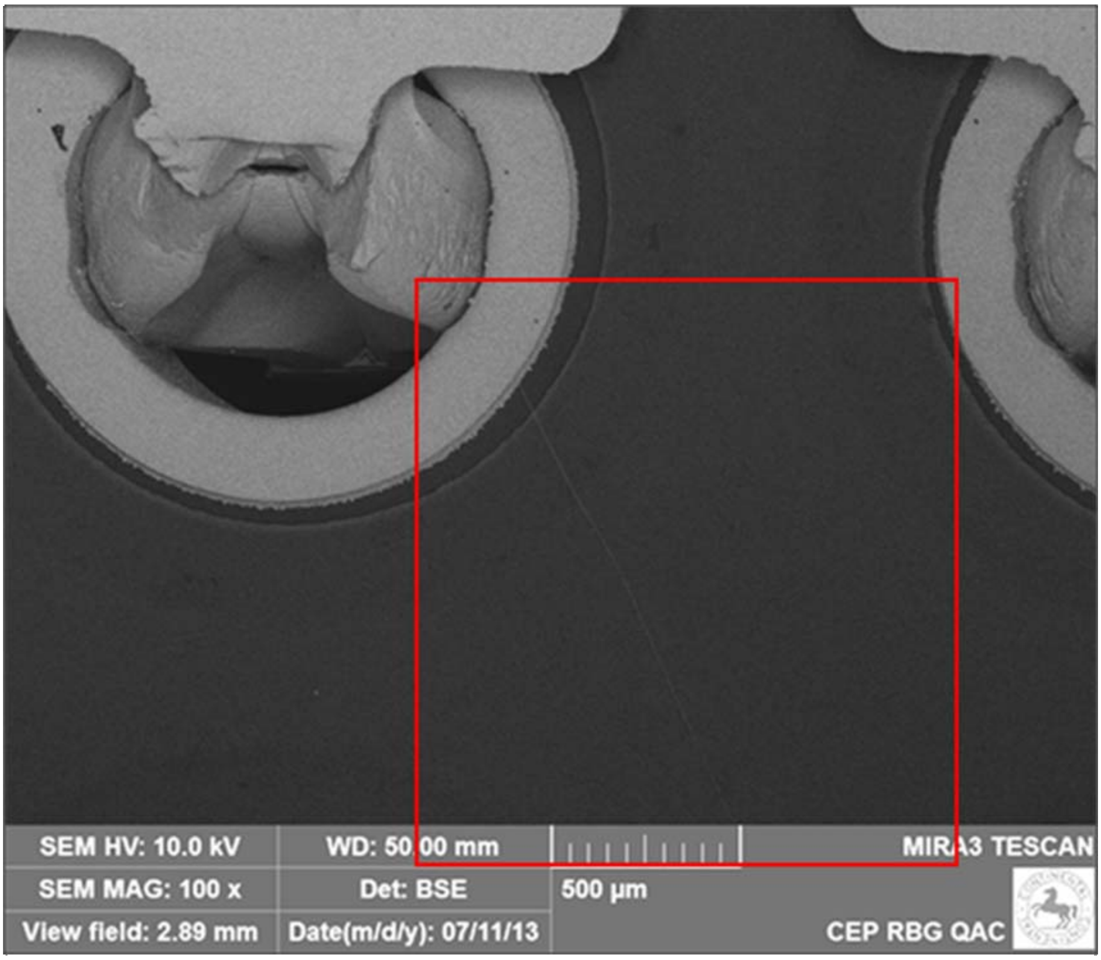


Figure 3: whisker formation at lead –free press fit contacts

Differences to RoHS

Compliant pin connectors in most "RoHS" equipment, in particular on complex PCBs like in high end servers, are used among other reasons because pin connections can be repaired and replaced. For repair, rework and upgrade e. g. of servers, the compliant pin connectors must be removable and reinsertable without causing damages to the pins or the plated through holes, and still work reliable (Gensch et al. 2009). Any bonding of the pins to the plated through hole (PTH) due to cold welding effects must be avoided in such uses under the scope of the RoHS Directive (Gensch et al. 2009)(Oeko et al. 2010).

This is a crucial difference between automotive and non-automotive press fit applications. While cold welding must be avoided in most RoHS equipment, it is the aspired effect in automotive pressfit applications. Cold welding of the pins to the PTH walls is necessary that the pin connector systems can reliably withstand the mechanical forces enacted onto them due to vibration and temperature changes, and the combination thereof. Pin movement in the holes would result in unreliable functionality. To achieve the cold welding effect, a higher pressure of the pin to the PTH wall is required. This higher pressure entails a higher force to insert the pins into the holes. ACEA et al. (2009o) claim that for pin connectors in telecom equipment typical insertion forces are 20 to 50 N/pin, while automotive pin connectors are inserted with forces up to 150 N/pin (Oeko et al. 2010).

Current Status

CoPiCS are wide spread in automotive applications with low to high pin count and in both comfort and security-relevant functions. Compliant pin connector systems are currently in use with both Sn and SnPb surface finishes. Since the last review in 2009 several cases of multiple customer returns of electronic devices caused by extensive whisker growth occurred when pure tin finishes had been used for pilot applications.

From literature it is known that stress gradients within the Sn surface is one of the driving forces for Sn whiskers. In all cases the insertion forces have been medium to high as described earlier. Due to the required reliability of automotive applications high retention forces are needed. High retention forces calls for high insertion forces which automatically results in high strain levels in the contact zone. This is the reason why at the border of the contact area between press-fit pin and PTH high stress gradients are present which tend to generate whisker growth with high probability of electrical short circuit. Even CoPiCS with high insertion forces which haven't been estimated highly prone to whisker growth due to their still moderate deformation shape showed whisker returns recently.

This leads to the conclusion that the occurrence of press-fit whiskers is not yet fully understood. This especially holds for the immersion tin layer production and resulting surface structures as well as the galvanic tin plating chemistry behavior and the interplay of these factors. The lack of knowledge led in all cases to a re-introduction of SnPb platings with a Pb-content of 5-10% which immediately solved the whisker issue. In detail the mechanism of Pb preventing SnPb from generating long whiskers is not understood so far. Therefore it is not possible yet to develop a substitute of Pb on a knowledge base with sufficient whisker suppression. Consequently mass production with an adequate substitute for Pb is not possible at the moment. There are three main demands to develop an adequate substitute for Pb:

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

2. In case no lead-free solutions are available, please describe the efforts that have been undertaken so far, to make the use of lead in CoPiCS avoidable.

Within the last years an Industry working group has been built in order to investigate the use of lead free CoPICS. In this working group a number of OEMs, Tier1s, Tier2s are working together to make lead avoidable as soon as possible.

1. Geometrical Change
   Oeko et al. 2010 recommended that the pins could be made smaller, and the holes be made bigger (Oeko et al. 2010). The automotive industry needs a cold welding effect for its connections. Cold welding effect needs high pressure between the pin and the PCB. If the geometry of the pins is changed these pressures will not be present between the pin and the PCB.

2. Thickness of tin-lead plating
   The thickness of the surface layer was reduced in order to reduce the amount of lead in the compliant pin connector systems.

3. Protection with lacquer layer
   Unfortunately a lacquer layer can't stop whisker growth. Tests showed that lacquer also lead to contact problems. Furthermore, the use of lacquer would result in additional resources and a big environmental impact.

4. Gold Surfaces
   Oeko et al. 2010 recommended to investigate gold surfaces. 2009 gold surfaces were rejected due to their insufficient cold welding properties (ACEA et al. 2009n), while the stakeholders in the RoHS Annex review rejected gold surfaces (Gensch et al. 2009) (Oeko et al. 2010).

   Nevertheless the automotive industry investigated gold-combinations. These combinations showed minor reliability results in test series, increasing resistance after temperature changes and less retention forces after vibration due to loss of cold welding effects. The gold connections could be described as brittle, intermetallic connection.

5. Alternative surface materials of pins and PCBs
   On a generic level, alternative surfaces that might replace SnPb as well as Sn have been evaluated and investigated. Due to our today's knowledge, specially treated Indium surfaces and certain SnAg compound surfaces might be candidates to partially replace today used surfaces.

   Both, SnAg and In(Indium)-bath chemistries were developed together with a specialized galvanic plating supplier for each plating in 2009-2011 with great efforts and costs on both sides, suppliers and Tier1s.
   A test program was set up in order to poof the long-term reliability by Design of Experiments, Process and Product-FMEA, Process controls and whisker tests. Now first experiences and results were taken by introducing SnAg in one pilot product field in series, since 2011 ongoing. For Indium first product validations are scheduled.
   Although the tests are running overall well sometimes sudden, unexpected peaks in the failure ratio appear.

   Further on transfer to high volume production from galvanic side and experience with other automotive applications is missing. At least this is a single source and just available in Germany. There is no solution worldwide available for SnAg and In galvanic.

   Beside metallic surfaces an extensive study investigates "press-fit at OSP (Organic Surface Protection)" as an alternative Sn-free PCB finish to avoid one possible source of whisker growth. The alternative PCB finish with OSP in combination with Sn, SnAg, and In pin surfaces increase the number of alternative surface combinations. The evaluation of the results is not finished yet, but show even higher insertion forces and PCB through hole deformation compared to immersion Sn PCBs. This indicates an increased risk for both, manufacturability and reliability. Besides, the combination OSP on PCB and Sn on the pin still shows too high whisker growth.

   Assessment of working group "Press fit in OSP PCB"
   - Press fit with OSP shows potential in future
   - Lower performance in comparison to state of the art
   - Shown weaknesses have to be ensured by
     - Further investigations on PCBs and Pins
     - Pilot projects between OEMs, Tier1s, Tier2s on components and vehicles level

3. Please indicate how much lead would be used under this application and substantiate the amount of lead with a calculation for vehicles put on the European market, and worldwide.

In order to estimate the amount of lead put into the market caused by this exemption following assumption has been made:

Value	Unit	Description
3.2	mm	Circumference of pin
7.0	mm	Length of surface
0.8	µm	Thickness of layer
7	%	Lead portion of layer
0.0012544	mm³	Volume of Pb per pin
0.011342	g/mm³	Specific mass density of lead
14.2274	µg	Weight of lead per pin
100	Pin/ECU	Number of pin per ECU
10	ECU/Car	Number of ECU per Car
71,490,000	Cars	Cars worldwide
13,430,000	**Cars**	**Cars in Europe**
1.0	t	Lead Worldwide
0.2	**t**	**Lead in Europe and year**

In last assumption of ACEA 2009 the estimation was around 0.8t (ACEA et al. 2009f). The lower amount of lead is mainly reached by taking thinner plating during the last years. Based on the assumption in Europe 0.2t (= 0,017 m³) of Lead are put into the market per year because of this exemption. Please note, that European law can only influence European legislation.

4. Please provide a roadmap towards ELV-compliance for applications where the use of lead in CoPiCS is still unavoidable. Please break down the roadmap into the stages to be preformed and present and explain the related timelines.

Within the next years the industry consortium will do further research. The pilot projects should mainly focus on Organic Surface Protection, change of basic PCB materials and lead-free pins. Unfortunately until now a lot of uncertainty and unknown topics occur during the development of surfaces of CoPiCS. The process is more similar to a research process and less to a development process. So it's not ensured that the milestones can be reached. The main development tasks are described as follows: .

Task 1: Finish Investigation
Hence, a replacement of the wide range of SnPb applications can't be reached in a short range time line. Generic investigations, e.g. at elevated temperatures, in miniaturized and high current applications are not finished or even started yet (time frame 3 years).

Task 2: Design and Product validation
Design and product validations need to be planned and performed and finally introduced on pilot projects to the field (time frame 3 years).

Task 3: Long-term reliability tests
It will take several years to gain enough field experience and roll-out the alternative plating to the diversity of applications in all presently known and future environments in light vehicles (time frame 5 years).

Task 4: Ramp-up production of lead-free CoPiCS
In parallel, the production of the alternative plating must be ensured on a worldwide basis. Today, prototype lines, one each for the two mentioned alternative plating finishes, exist for a relatively low amount of pins. The galvanic set-up needs to be transferred to the different economic regions (time frame 3 years). A reasonable supplier portfolio needs to be built-up (time frame 5 years).

Because of the uncertainty an extension of the exemption 8f with review date is highly requested from ACEA et al.

Source of information: Expert Information ACEA et al.

Date: 4 November 2013

References

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