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(g)

Review of exemption 8(g) "Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit flip chip packages"

Input of the automotive industry expert group, represented by ACEA, JAMA, KAMA, CLEPA, et al.
Base of the contribution has been provided by CLEPA and completed by other associations.

We would like to express our opinion concerning consultation on exemption No. 8(g) of Annex II of Directive 2000/53/EC (ELV Directive) to effect that the exemption should be continued and substitution would be difficult.

The above mentioned industry stakeholders request continuation of the exemption.

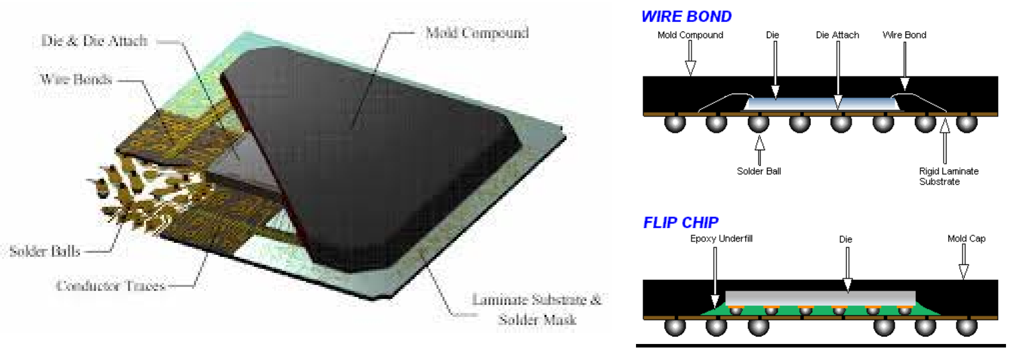
Questions & Answers

1. ***Please explain whether the use of lead in this application is still unavoidable so that Art. 4(2)(b)(ii) of the ELV Directive would justify the continuation of the exemption.***

   Flip chip interconnection technology is used in high complex multi-chip and stacked package integrated circuits (e.g. controllers for communication equipment). The technology offers advantages in high frequency (HF) applications where heat dissipation and radiation (heat as well as electromagnetic) is critical. Controllers using these advantages can be found in a wide variety of uses in vehicles, e.g.

   - Long range distance control;
   - lane departure warning systems;
   - frontal projection systems;
   - car radio;
   - vision systems;
   - car-infotainment;
   - traffic sign recognition;
   - navigation systems;
   - telematic systems;
   - head-up displays.

   Fig. 1 shows the typical design of flip chip devices in comparison to traditional design using wire bond connections.



   <u>Fig. 1:</u> flip chip device

   As of today, a significant number of existing automotive flip chip applications cannot be converted into lead-free.

   Main reasons are,

   - that products use chip sizes > 300 mm^2 or fabrication processes using structures of 90 nm and above or / and additional solder die attach;
   - that the incremental stress from the Cu pillars or other lead-free materials introduce severe long term reliability problems such as bump integrity, dielectric cracking and die cracking;
   - the influence of cooling parameters having more influence on microstructure; [1]
   - the thermo mechanical load during the processing of the flips chips, which limits the achievable and required long term reliability;
   - in vehicle use the component has to tolerate high mechanical and thermal stress over a long period of time.

[1] S. Wiesse: Verformung und Schädigung von Werkstoffen der Aufbau- und Verbindungstechnik e.g. p 455 ff; Springer Verlag Heidelberg 2010 ff

For designs based upon older CMOS technology with 90nm or larger printed transistor line width, the chip design, factory design and process technology is often not compatible with the stiff Pb-free flip chip bumps. The conversion to Pb-free bumps results in reliability failures. Similarly, products in semiconductor manufacturing technologies with a die size greater than 300 mm^2 do not meet automotive long term reliability requirements. The large dies are especially susceptible to bump failures near the corners when using stiff or less pliable Pb-free bumps.

Newly developed lead free flip chip products are available for die sizes less than 300 mm^2 and less than 90nm node structures, but by far not yet covering all the various products, designs and applications in current uses described above. For these products, long term reliability and performance under harsh environment still has to be assessed and field experience gained. These lead free flip-chip applications typically fail the essential AEC-Q 100[2] specification for the endurance demands; thus excluding their usage for automotive applications.

2. ***In case the substitution of lead is not viable, please explain the efforts you undertook to find a lead-free alternative.***

Significant progress has been made to develop alternative interconnection and packaging technologies. However, challenges remain with regard to the use of substitute materials and interconnection technologies.
Newly designed products using that substitute may not be suitable for existing and forthcoming applications in vehicles, especially, when considering new technology fields like (H)EV and the requirements on components resulting from thereof. These developments are currently ongoing, but still will need much effort within the automotive industry and related supply chain for successful completion.

Automotive flip chip technology is relatively new. Applications such as engine control or advanced traffic control and passenger safety systems (e.g. “eCall”) require advanced solutions, where lead free flip chip may not be possible.

The semiconductor industry has been converting new products to lead-free flip chip bumps and has launched extensive design and development activities to find lead free alternatives for automotive industry. These lead-free technologies have been introduced for product designs using structures less than 90nm in width and with an area less than $300mm^2$. New materials for lead-free flip chip connections have been developed and implemented, such as copper pillars. The wafer fabrication technologies less than 90nm were designed for lead-free bumps. With the shrinking fabrication geometries, the die become smaller and create less stress on the bonding pads and circuitry as temperatures change and packages flex. Also, the new technologies were designed with a more robust wafer stack in the fabrication process, able to withstand the additional stress. As a result, many flip chip devices contain lead-free bumps for connecting the die to the integrated semiconductor package but are not yet available and/or qualified for automotive applications as described above.

Manufacturers have unsuccessfully attempted to retrofit lead-free bumps onto older and larger technology products designed for lead bumps. When attempted, the increased stress from the rigid lead-free bump resulted in product reliability failures. Due to quality and reliability concerns, some contract assembly sites do not offer lead-free flip chip bumps for the older and larger die, so there may be no alternative available for these products.

[2] http://www.aecouncil.com/AECDocuments.html

Although the semiconductor industry is known for rapid product innovation, products in vehicles have a long life cycle. Flip chip connections are used on high power, high reliability and high performance products. In these applications, the OEM market demands full characterization of all possible chip defects. This historical information is only available through years of evaluation. Product delivery for product replacement and repair and for other highly custom and low volume applications may continue for decades after a product passes its peak sales volume. Companies may ship inventory that was fabricated years ago for these low volume products. This further complicates attempts to redesign with lead-free materials during the tail-end of a product life cycle.

ELV exemption 8g continues to be essential.

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.***

The typical lead content for a lead flip chip die within a semiconductor product may vary from a minimum 0.0005 grams to a maximum 0.3 grams, depending primarily upon the size and number of bumps. The median estimated lead from flip chip bumps under ELV is 0.015 grams.

The flip chip products are used in selected few sockets within automotive applications. There are no metrics to identify the number of lead flip chip components within an average vehicle. Assuming one to three flip chip components per vehicle, based upon the latest estimated 13.4 million registered units in the EU + EFTA, the total lead placed on the EU market is estimated at about 0.2 to 0.6 metric tons per year.

4. ***Please provide a roadmap towards ELV-compliance if the use of lead is still unavoidable. Please break down the roadmap into stages to be performed and present and explain the related timelines.***

For selected high power, high reliability and/or high performance products, the ELV exemption 8g shall be required during the development and evaluation of substitute materials and interconnection technologies. Specifically, exemption 8g shall be necessary:
- Until replacement materials and processes are successfully identified for large die, high power and high reliability products;
- Until long term reliability is assessed and qualified under the harsh environmental conditions of use in vehicles according to automotive specifications (e.g. AEC-Q100); and,
- Until products become available for automotive applications from a reasonable number of suppliers and in sufficient quantity.

Extension of ELV exemption 8g is essential because:
- Concerned applications for these products include safety critical applications like “emergency call”, “car to car communication” and applications in regulated areas like “telematics”;
- The development and transition cycles in the global automotive industry can extend beyond a decade; and,
- Flip chip technology supports the ongoing miniaturization of components and contributes to resource efficiency.

> After an automotive suitable, lead free material is identified and material / process development is frozen, usually a minimum of 6 years will be required to qualify the new material through the whole supply chain. Based upon the current status of these special products, it is not possible to estimate a transition date. Product delivery for replacement and repair will need to continue for the life of type approved vehicles.

Based on the findings as listed above, the automotive industry stakeholders request a continuation of exemption 8g.

Date: 4 November 2013

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