<u>Enclosure 3</u>: Non low melting point related obstacles

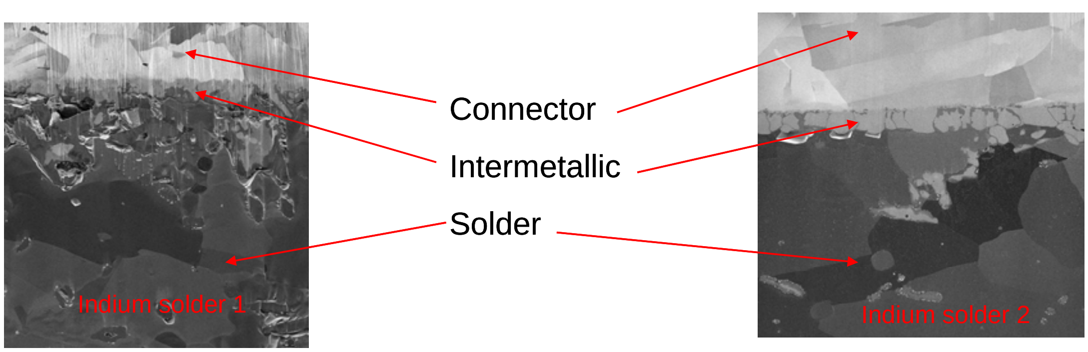
This enclosure gives information and data on non-low-melting temperature related obstacles i.e.:

- 3.1 Instability of Indium Solders
- 3.2 Corrosion of Indium Solders
- 3.3 Unsuitability of Other Lead Free Solder Types
- 3.4 Indium Resource Availability
- 3.5 LCI Considerations
- 3.6 Recycling Aspects
- 3.7 Other Environmental Issues.
- 3.8 Conclusion

3.1 Instability of Indium Solders

When used with standard commercially available connectors applied on automotive glass products Indium solders form harmful intermetallics which result in cracks in the soldered joint. The intermetallics are present immediately after soldering and grow in size with time.

The figure 3.1.1 and 3.1.2 below shows the intermetallic component present immediately after soldering.



<u>figure 3.1.1</u> and <u>3.1.2</u>: intermetallics in Indium solder directly after soldering

The figure3.1.3 below shows the growth of intermetallic layers and formation of cracks after environmental conditioning.

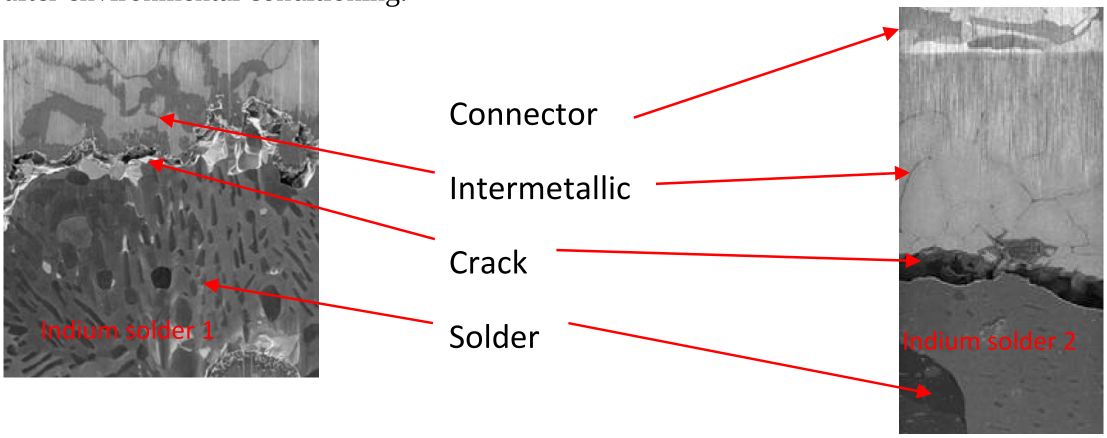


figure 3.1.3 growth of intermetallics in Indium solder over time

It accelerates by high temperature (growth velocity increases with temperature) but occurs more slowly at lower temperatures. The soldered connection is unstable.

The unstable behavior of these Indium based solders is not acceptable; a failure of the solder joint is inevitable.

This in line with the following result (see figure 3.1.4) of a supplier analysis on Indium solder glass after humidity treatment. Micro-Cracks can be observed, which are not accepted. These failure “messengers “ can not be detected by visual inspection, but under optical microscopy.

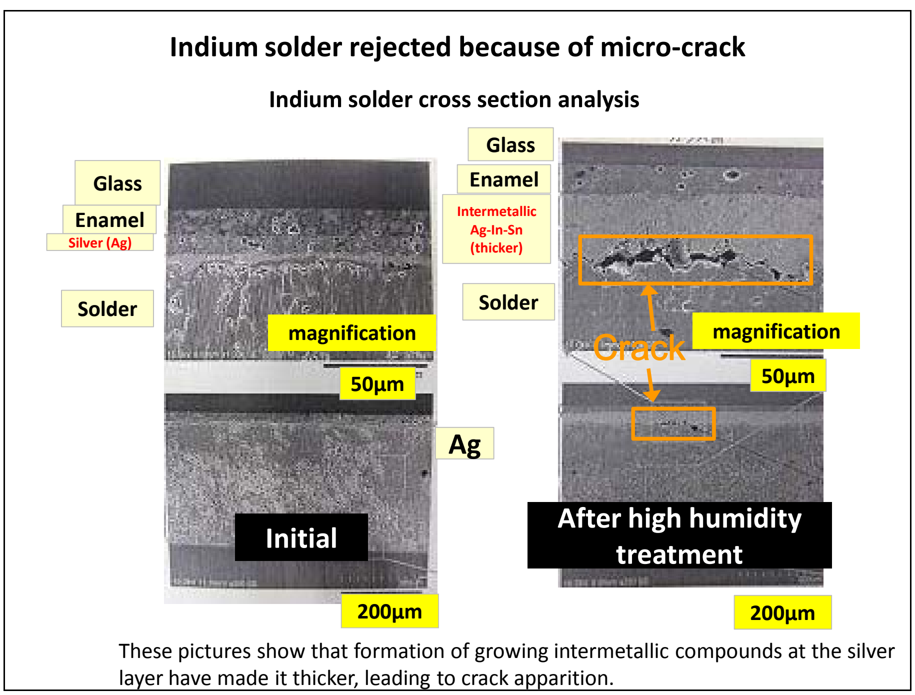


figure 3.1.4: formation of microcracks in Indium based solder after humidity treatment

3.2 Corrosion of Indium Solders

- Indium solders corrode more in humidity tests and salt spray exposure – both of which are required by the vehicle manufacturers. Figure 3.2.1 demonstrates the different corrosion behavior of lead based solder and of Indium based solder.

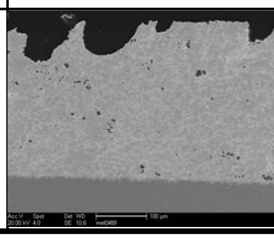
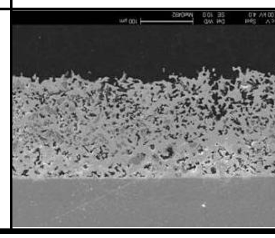
Test	Lead Solder	Indium Solder
Humidity Exposure (Optical images)		
Salt Spray (SEM Cross section)		

Figure 3.2.1: lead based and Indium based solder after salt spray exposure

Vehicles have to fulfill their functions also in coastal regions. The resistance to deterioration of the component after salt spray exposure has to be considered in the design of the product.

3.3 Unsuitability of Other Lead Free Solder Types

The search for suitable Pb free solders for automotive glass products has been on-going for at least 10 years and many variants have been tested. Alternative materials to Indium based solders are Tin (Sn) based and Bismuth (Bi) based. To assess the suitability of these types of solders two of the better materials were tested against the up-dated draft-OEM test specification referred to in section 1.4 above. The results are shown in the table 3.3.1 below.

Test Description	Specification	Bi solder	Sn solder	Pb Solder
Temperature cycling test according to DIN EN ISO 16750-4-H section 5.3.1.2	-40C to +105C, Humidity not controlled (dry), Electrical current loading with 14V (+/-0.2) starting at end of low temperature phase - 60 cycles (20 days)	Fail	Fail	Pass
Heat soak test according to DIN EN ISO 16750-4-K section 5.1.2.2	Glass at 105°C Electrical current loading with 14V (+/- 0.2) throughout the test. 6N mechanical load to soldering joints during heat storage. 96 hours	Pass	Pass	Pass
High temperature storage test	Temperature: 120°C; No mechanical load and no electrical load during the test. 24 hours	Pass	Pass	Pass
Long term test without mechanical load	Glass at 105˚C, Electrical current loading with 14V (+/- 0.2) throughout the test, no mechanical load on connector. 500 hours	Pass	Pass	Pass
Heat shock test (water splash) according to DIN EN ISO 16750-4-H. Splash water following section 5.4.2	Heat glass to 105˚C and keep at this temperature for 1 hour Remove from oven and within 20 seconds pour 3 litres of water at 23 +/- 5˚C onto the outside face (not on the connectors).	Not tested	Not tested	Not tested
High Humidity test: constant climate following DIN EN ISO 6270-2-CH	Storage at: 80˚C, 96 - 100%RH, After 10 hours, 14V applied for 15 minutes (chamber 85°C) then switched off, applied again after 24 hours and repeated until the end of the test. No mechanical load on connectors, no voltage applied. 500 hours.	Pass	Pass	Pass
Glass washing liquid test	Immersion in washing liquid consisting of 69,5 Vol% water 20 Vol% ethanol 10 Vol% isopropanol 0.09 Weight% sodium lauryl sulphate 0.5 weight % ethylene glycol	Not tested	Not tested	Not tested
Salt Spray Test according to DIN EN ISO 9227 (ISO 50021)	5% salt solution, 35°C. No voltage applied, no mechanical load applied. 96 hours	Not tested	Not tested	Not tested

Table 3.3.1: Survey on test results Bi and Sn based solder in comparison with Pb based solder

It can be seen from the results that these alternative Pb free solders also failed the test specification. The lead containing solder of current production passed the test specification.

Further results on tested solder substitutes are summarized in enclosure 2 (industry activity report 2009 – 2011).

3.4 Indium Resource Availability

Indium has been identified as a critical raw material[1], as recently investigated by the EU Commission. [2]

Indium therefore was put on the EU´s list of critical raw materials in 2010.

Because of its long term availability is not something that can be guaranteed and the industry can not rely on it to replace lead in solders.

Indium use is essential e.g. for the production of certain solar cell types [3] (thin film), for the production of ITO (Indium tin oxide layers) in LCD displays and specific semiconductors. Even in white LED´s used for energy efficient illumination Indium is needed. With 500 to 600 t /a annual worldwide production Indium is very rare and in about 6 years it is expected that demand will exceed current production capacity [4]. In solders for soldering on automotive glass Indium is not essential.

Replacing lead in the specific automotive application by Indium would influence the Indium availability for these applications and sharpen the critical Indium availability.

The limited Indium availability and the scarcity is reflected in volatile high prices. The price for one kg of Indium currently is [5] around 800 USD, whereas one kg of lead is around 2.4 USD.

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[1] http://ec.europa.eu/enterprise/policies/raw-materials/critical/index_en.htm ; 16.8.2011;

[2] EC communication COM(2011)25

3 D.I. Bleiwas: Byproduct Mineral Commodities Used for the Production of Photovoltaic Cells; U.S. Department of the Interior / U.S. Geological Survey Circular 1365; Virginia 2010;

[4] Behrendt, Scharp, Kahlenborn, Bleischwitz et alt.: Seltene Metalle Maßnahmen und Konzepte zur Lösung des Problems konfliktverschärfender Rohstoffausbeutung am Beispiel Coltan; Herausgeber: Umweltbundesamt Dessau, März 2007 Internet: http://www.umweltdaten.de/publikationen/fpdf-l/3182.pdf page 6 ff and page 14f

[5] http://www.metalprices.com/pubcharts/Public/Indium_Price_Charts.asp?WeightSelect=KG&SizeSelect=M&ccs=1011&cid=0; 29.08.2011;

3.5 LCI Considerations

Substitutes introduced because of material restrictions should have proven environmental benefits. If the use of a substitute creates more negative environmental impact or causes more environmental burdens the substitute is not a suitable alternative to an existing solution.

Seen from a life cycle analysis approach - for its mining and producing and recycling, Indium is a very high energy consuming metal. Whereas production of 1 kg of lead consumes around 20 MJ/kg the production of one kilogram of Indium consumes around 8,290 MJ/kg and 600 kg of CO_2.[6] So the production of one kilogram Indium requires 400 x more energy than the production of lead.

Because an updated validated LCI dataset for Indium was available yet at beginning of Sept. 2011 the preparation of a complete LCA was not possible up to now and will be the subject of automotive industry activity within the next month. Already now it can be assumed that the use of Indium in this application as substitute of lead will cause very significant higher environmental burdens than the current use of lead.

Based on this new scientific based information we oppose against the use of Indium in this application because of its negative environmental impact.

3.6 Recycling Aspects

Because of the ELV directive being a waste and recycling oriented legislation these aspects have to be covered here.

The specific provisions of the ELV directive and the elements of the European waste legislation ensure that end-of-life vehicles (ELV´s) as well as waste from the repair and maintenance of vehicles enter well defined utilization and recycling paths. For example this is based on the fact that vehicles have to be registered and deregistered. This is a significant difference to other waste sources, where smaller appliances and parts are not always entering the foreseen utilization routes.

3.6.1 Treatment of Vehicle Glazing from End of Life Vehicles

The current trend in the recycling of vehicle glazing is for the glass to remain in the vehicle when it is sent for shredding. In the shredding process the glass is broken into small fragments. Any solder will remain adhered to the "T" piece and connector wiring together with some small glass fragments. The predominately metal pieces pass on through the separation process. Ferrous materials are separated in a magnetic field. Aluminum, using eddy current technology and non-ferrous materials, including copper, are separated in the dense media separation section of the process. The solder content is passed on with the copper based waste stream for recycling.

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[6] Sources: GaBi LCA database Lead 20 MJ/kg; PE International LCI data Indium Sept.2011 (not published yet; the data can be made accessible on request for OI) P.E.D renewable and nonrenewable resources Indium 8.290 MJ/kg

A specific recycling of Indium based solders is not possible and the used Indium will end as tramp element in other recycled metals or in residues of further metals refining processes. So Indium will be lost by dissipation, whereas the conventional solder enters the established recycling routes and is recovered.

The glass is included in a mixed aggregate stream consisting of stone and brick etc. which is used as a secondary aggregate material for road making, pipe laying and building construction work.

3.7 Other Environmental Issues

3.7.1 Risk Assessment for Indium

Although Indium is in discussion to be a possible alternative for lead in this application it is recommended that EU Commission considers risk assessment aspects regarding ecotoxicity and adverse effects in humans of Indium before making any decision for substitution.

Some toxicological investigations have shown that Indium compounds[7] can create a lot of adverse effects regarding health and environment. Expanding usage of Indium should not be recommended until comprehensive data about Indium and Indium compounds are published. Assuming that Indium is used in EU in a quantity above 100 t /a, the risk assessment should be available until 2013 for final registration under REACh.

3.7.2 Processing of lead containing solders in production

During processing of the lead containing solder in assembling solder joints to vehicle screens state of the art devices prevent exposure of workers to solder dust. This is also in line with EU occupational health regulations. There is no evidence of any challenge known.

3.8 Conclusion

Seen from the perspective of the total environmental impact and the critical resource availability the use of Indium in this application is very questionable. The inevitable loss of Indium in this application during vehicle utilization and the high environmental load of Indium disqualify this material in this application for being a substitute because of the negative overall environmental impact.

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[7] G. Ungváry, E. Szakmáry, E. Tátrai, A. Hudák, M. Náray, V. Morvai: *Embryotoxic and teratogenic effects of indium chloride in rats and rabbits*. In: *J. Toxicol. Environ. Health A.* 2000, 1, 59, S. 27–42.