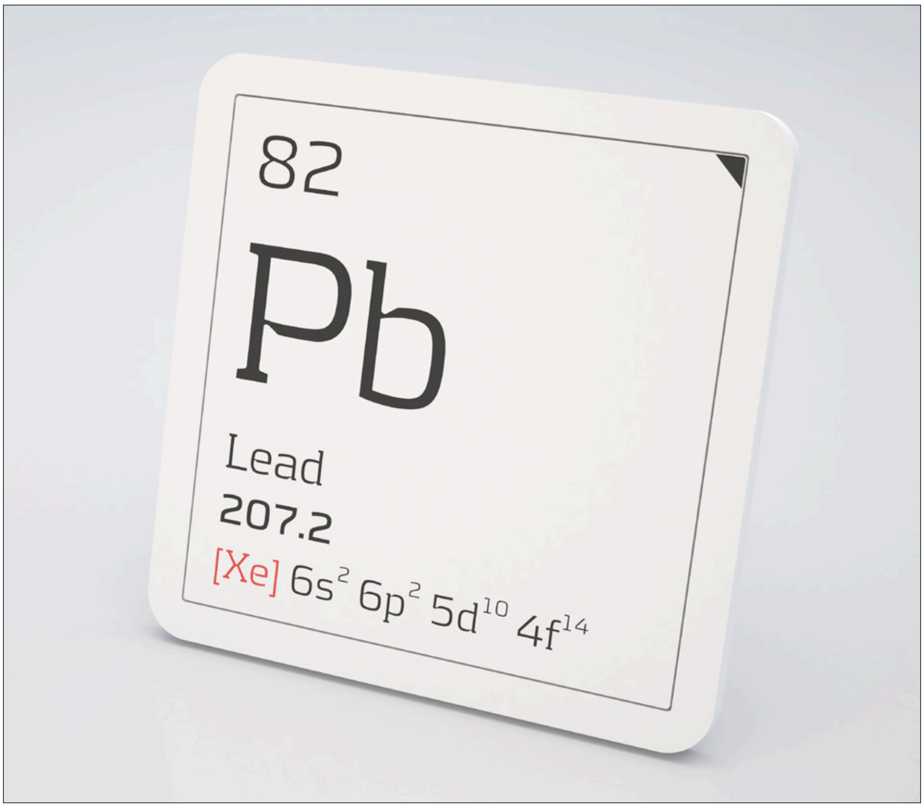
The New Generation of Lead-Free Alloys

You can't have everything. Yes, you can.

By **Michael Mendel** — Managing Director, Almit (Germany)

The European Union (EU) directives RoHS I of 2003 and RoHS II of 2013 regulate the use of lead and other toxic substances, such as mercury and hexavalent chromium within the EU. These directives also cover lead-containing soldering composites that have since only been allowed to be processed in exceptional cases. For a long time, the problem was that lead-free soldering composites of the first generation did not reach the performance of lead-containing alloys. But much has happened in recent years.

Lead, with its symbol Pb (from Latin: plumbum), is known to be a toxic heavy metal that not only pollutes the environment, but is also capable of accumulating in the human body — particularly in bones, teeth, and the brain — and of causing impairments to health. In Germany, as much as 20,000 tons of lead were still processed to soldering material in 1998. Today, the use of lead has been reduced to a minimum and is completely prohibited by the RoHS directives for conventional applications, such as consumer electronics. The health risks were offset by the excellent properties of lead as a component of alloys. Lead is corrosion-resistant, has a high density, is easy to process, and guarantees particularly high strength. These properties made tin-lead (SnPb) solders an integral part and reliable factor in manufacturing all over the world, for many decades. It wouldn't be possible to manage without lead, would it?



Looking for alternatives

Forced by the legal provisions, it was necessary to find alternative solutions to replace the tried and tested tin-lead solder (SnPb). It goes without saying that the requirements were for such alternative solutions to provide the same favourable properties of the now prohibited lead-containing alloys. Easier said than done. The fundamental problem in lead-free alloys is the lack of the "soft" component lead within the alloys. This means, on the one hand, that lead-free soldering points are less likely to deform under load; on the other hand, the stress loads are increased at the solder points. This in turn increases the probability of the occurrence of micro-cracks. Micro-cracks are one of the main reasons for defective soldering points and ultimately cause material fatigue.

The first generation did not meet expectations

The lead-free alloys that were offered on the market after the RoHS directives came into force — let's call them the first generation — did not meet the user's expectations. The issues with these types of alloys, for example SAC305 and SAC0307, are widely known. On the one hand, they do not achieve the performance of the previously used lead-containing alloys at any time. On the other hand, due to the high silver content (SAC305 contains 3%), these alloys are very expensive. The impact of these conditions for the users becomes obvious when taking a look at the price development of silvers during recent years. While around the turn of the millennium, the price for one kilogram of silver was €156, in 2015 the average price for the same

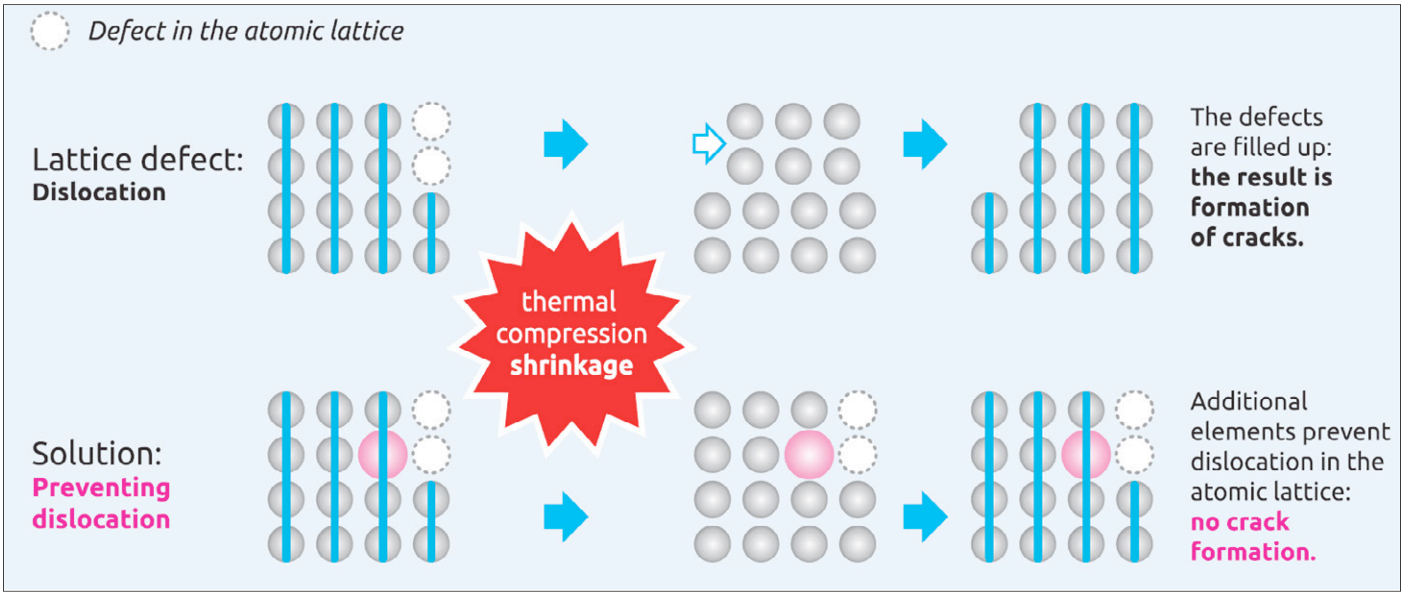


Figure 1: The benefits of a bismuth alloy explained by the example of a lattice model: Every substance or material consists of atoms. During the solidification process, "dislocation" of atoms takes place. This disturbs the lattice structure and increases the risk of later formation of cracks. Bismuth prevents "dislocation" of atoms by "filling" the gaps.

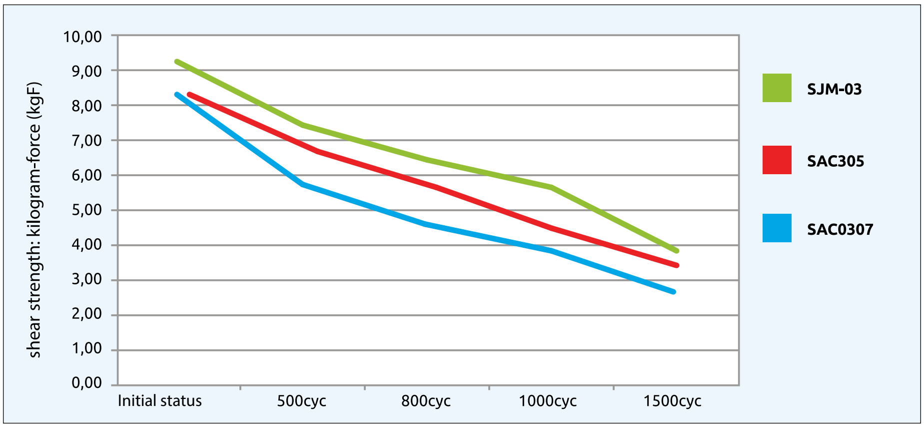


Figure 2: Shearing strength (fatigue failure), comparison of SJM and SAC. Test conditions: temperature range − 40ºC~+125ºC, dwell time 30 minutes, component 3216, chip resistance, test: pressure acting on component at 1 mm/min and strength measurement

amount was €454. This must be what a horror scenario looks like for controllers in companies.

New generation, new opportunities

However, the time of the first-generation lead-free alloys (i.e., when SAC was considered to be the only suitable option) is over. Today, there are lead-free alternatives available that provide equal properties as lead-containing alloys and even surpass them. The SJM product range is the first to be mentioned in this context. The acronym SJM stands for Strong Joint Metal, which is in reference to the excellent performance of these types of alloys. The special feature of the alloys from the SJM range is that they provide properties that were previously considered to be incompatible. Despite their very low silver content (and consequently their much more favourable prices), SJM alloys are very reliable and provide excellent tensile and tear strength. This refutes the statement that "you can't have everything," because with the SJM range you can.

In the meantime, many users — among whom there are renowned manufacturers from the automotive industry — have realised that they can have everything and changed from SAC305 to SJM-03. One does not need to be a prophet to predict that SJM-03 (Sn-0.3Ag-0.7Cu-2.0Bi) has great potential to become the new standard alloy and to thus be the successor of SAC305. However, the state-of-the-art with regard to strength even at great temperature variations is another alloy from the SJM range: SJM-40 (Sn-4.0Ag-2.0Bi-3.0Sb) with a higher silver content.

Future through research and innovation

The improvements that have been achieved in the field of lead-free, low-silver alloys are due to intensive research and new innovative approaches. A well-known substance has played a major role in these developments: bismuth (**Figure 1**). Bismuth is a semimetal (element system Bi) and belongs to the group of atoxic or very low toxic heavy metals. Bismuth alloys are in no way inferior to SnPb solders with regard to elasticity and shearing strength (**Figure 2**). The benefits that bismuth provides with regard to tear strength of the soldering point during the solidification process are more easily understood if bismuth is pictured as a number of atoms structured in a lattice. During solidification, the atoms "dislocate," which ultimately may cause formation of cracks. Broadly speaking, bismuth prevents dislocation of the atoms. Another advantage of bismuth is its low melting point that opens up new opportunities, particularly for rather heat-sensitive components. Overall, bismuth may be considered an adequate and contemporary replacement of lead.

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Which lead-free alloy is best suited to my needs?

Last but not least, users are faced with the question: Which lead-free alloy is the right one for me and my applications? There is a large variety of products available for selection. So, how can users make sure to make right decisions? The measure of all things is and will be personal assistance and specific, competent consulting by specialists from the manufacturers' and suppliers' side. Only in personal meetings it is possible to discuss requirements for soldering, define them in detail, and find a perfectly adapted solution. ◀

The Author

Michael Mendel is Managing Director of Almit Germany, which is one of the major suppliers of soldering materials world-wide and keeps imposing new standards on the market with their innovative products, such as the KR-19RMA solder that has been used by NASA for the construction of space shuttles. For more information or if you wish to make a personal appointment, please call 06061 96925 0 or write to info@almit.de.

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