Reliability of Lead-Free (LF) Solder Joints

Werner Engelmaier

Just in case Brussels goes ahead with the ill-advised environmentally unfriendly directive of banning lead in solders, it is prudent to examine the reliability implications of this. It took some 30 years to understand Sn/Pb solders; LF-solders are even more complex.

Lest somebody gets the wrong impression that I support the move away from the standard lead-(Pb) bearing solders to lead-free (LF) solders, let me make my position absolutely clear—this move is a cynical exploitation for commercial interests of false misguided fears trying to replace a material, Pb-bearing solders, without any proven environmental problems, with materials which are far less environmentally friendly.

That said, just in case Brussels will not see the light, it is prudent to examine the reliability implications of such a move.

To look at all the possible candidate materials is way beyond the scope of this column; thus, I will concentrate on the SAC (SnAgCu) solders, which are the front runners for the consortia working these issues: NEMI (USA)—Sn3.9Ag0.6Cu, IDEALS (EU)—Sn3.8Ag0.7Cu, JEIDA (Japan)—Sn3.5Ag0.75Cu.

To further limit the scope here, I will not discuss the obvious problems associated with SAC-solders, such as tin whisker formation and the possibility of electrical shorts, reflow temperatures about 40°C higher than the near-eutectic Sn/Pb solders and the consequences for both components and PWBs as well as the increased energy consumption, and the possible uncontrolled mixing together of different solders during assembly. Further, the higher dissolution rates of copper and other metals in the high-tin SAC-solders can create problems with thinner copper in the PTH/PTV interconnect structures of PWBs as well as IMC collecting at the bottom of wave solder pots, will not be discussed here.

It needs to be stated up front, that at this time not enough data exists for the development of creep-fatigue models for LF-solders, and thus no acceleration factors for accelerated thermal cycling (ATC) to operational life are possible. We do however, have enough data to determine that the reliability issues for LF-solders, SAC-solders included, are even more complex than it is for Sn/Pb solders.

Looking at the diverse data available, it can generally be stated that in comparison to Sn/Pb-solders SAC-solders are somewhat stronger, creep slower, have a larger scatter of material properties and characteristics, and have wider creep-fatigue failure distributions. Further, any rank-ordering is dependent on SJ geometry, soldering surface finishes, test condition severity, and failure statistics [Nf(1%) vs. Nf(50%)/Nf(63.2%)].

This behavior can be captured to some degree in a generalized way as shown in *Figure 1*.

The four graphs in *Figure 1* illustrate why so much of the reliability data for LF-solders seems contradictory. Depending on the severity of the accelerated thermal cycling (ATC) and the testing details different relative results are obtained. The four graphs also project to the fatigue behavior likely for SAC-solders at the product operational level; however, since for LF-solders the test data are insufficient for the development of acceleration models and no product reliability results exist, these projections need to be understood in those terms.

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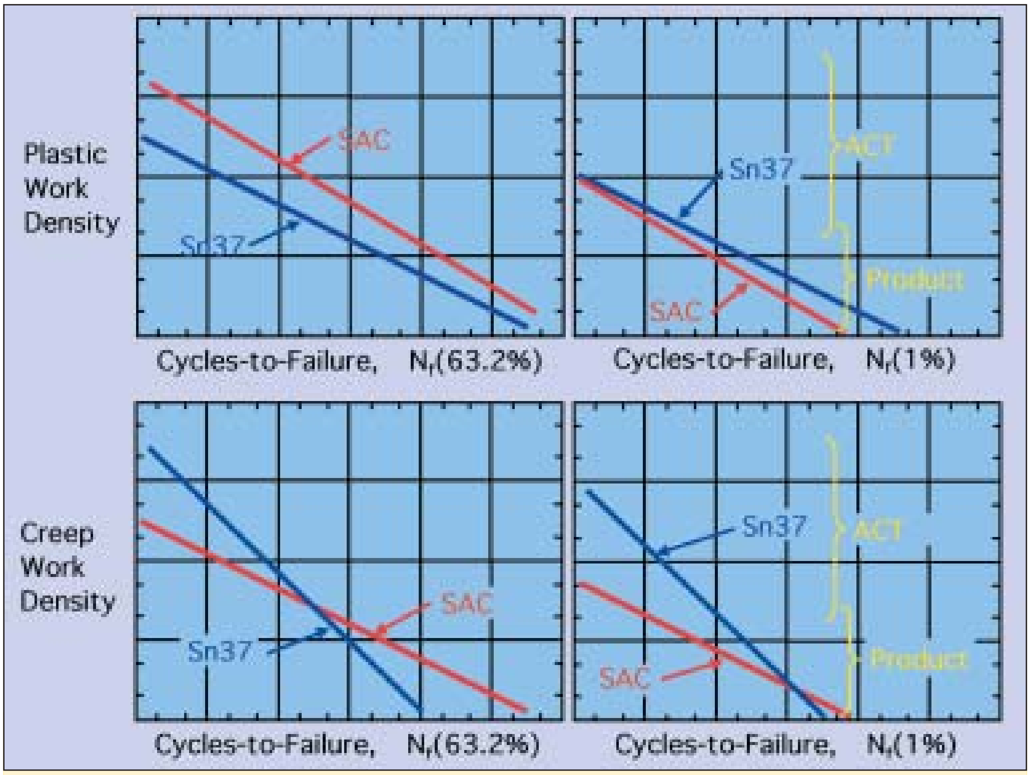

Figure 1: Generalized fatigue life responses for Sn37Pb and SAC solders to different levels of cyclic plastic work density and creep work density at Weibull failure percentages of 63.2 and 1%.

It took some 30 years of effort by many researchers at many of the research laboratories of OEMs all over the world to get a sufficient understanding of the creep-fatigue behavior of Sn/Pb solders. Many of these laboratories no longer exist, certainly not with the same capabilities, having fallen victim to the economic conditions-how long will it take to arrive at a sufficient level of understanding of LF-solders?

So, what to do in the meantime? My recommendation is to assure reliability with accelerated testing that is relatively close to the field operating conditions and follow the procedures given in IPC-9701 “Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments.” While IPC-9701 was not developed with LF-solders in mind, the principles underlying this standard are equally applicable to LF-solders.

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