SECOND GENERATION Pb-FREE ALLOYS

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ABSTRACT

This paper will discuss the shortcomings of current LF alloys (namely SAC305) and present recent data for various new alloys which show promise as replacement materials. These newer alloys offer important reliability improvements but do have some issue that need resolution before mass implementation. Shock and vibration data will be provided, as well as thermal cycle data. The primary focus will be on SnCuNi and SAC105X alloys and how they can be used effectively in the Pb-free electronics industry going forward.

Keywords: Pb-free, solder, reliability, SnCuNi, SAC105.

INTRODUCTION

It has been a full 3 years since RoHS went into effect and Pb-free products hit the market in high volume. Many companies had only 1-2 years to prepare ahead of the deadline. Though there was a wide assortment of Pb-free alloys available to choose from at the time, Sn-Ag-Cu (SAC) alloys eventually won out. SAC305 (3%Ag and 0.5%Cu) became the primary alloy adopted for surface mount solder paste and solder balls on ball grid array (BGA) packages. Since 2005, hundreds of millions of products have been built with SAC305 solder and these products covered a wide range of applications from hand held devices and notebook computers up to work stations and servers. From this wide spread use and a few years of field reliability to draw on, there is now a much better understanding of the strengths and weaknesses of SAC alloys, both which will be discussed in greater detail in this paper. There has been a great deal of alternative Pb-free solder development work performed in the industry to improve on the properties of SAC305.[1] Industries that have thus far been exempt from Pb-free requirements are in a good position to benefit from the lessons learned and adopt Pb-free alloys that will better suit the requirements of their products. Such industries would include medical, defense, aerospace, measurement equipment, and makers of high end routers, storage, and server systems.

BACKGROUND

Much of the initial investigation of SAC alloys is credited to Consortia efforts by NCMS and iNEMI. SAC alloys (particularly those with 3-4%Ag) were advantageous because their liquidus temperature was near 217°C. This melting temperature was significantly greater than eutectic SnPb (183°C) but less than many of the other Pb-free options. There was an early debate over whether SAC305 or SAC405 was better. Reliability data was similar between the two, but eventually SAC305 won out. The lower cost from reduced silver was only a small factor considering that the cost of a solder paste is primarily driven by fabrication costs and not cost of the metal in it. The more significant reason was a reduced volume fraction of Ag_3Sn precipitates which decreased the flow stress and made the alloy more compliant, as shown in Figure 1.

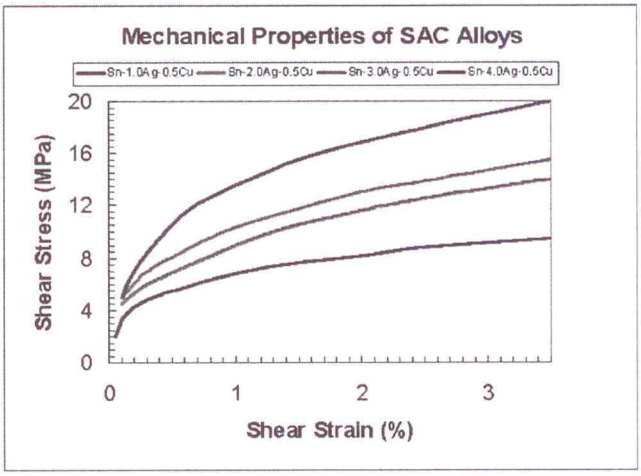

Figure 1: Shear stress-strain curves for SAC alloys with varying amounts of Ag (1-4%).[2]

A handful of other alloys were being seriously considered as the primary Pb-free alloy back in the 2003 timeframe. The following is a list of some of them along with a brief explanation of why they were not selected for surface mount applications.

SnCu

SnCu(0.5-0.9%Cu) had the benefit of low cost when compared to other alternatives and royalties were not an issue. However, its liquidus temperature of 227°C was a full 10°C higher than SAC and its wetting properties were not as favorable. With the concern for heat damage to boards and components, the extra 10°C was undesireable. However, SnCu did gain use as a wave solder alloy for more simple PCBs with easy to fill vias. The poor wetting properties (bridging and inadequate hole fill) make it insufficient for more challenging applications. For this reason SAC was initially adopted for many wave solder operations which was quite costly (over 2 times the cost of Sn-Cu) and resulted in high copper dissolution.