Reliability of Solder Joints - Determination, Statistical Analysis and Dependencies to other Characteristics

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Summary: The reliability of solder joints is one important part of the quality of SMT-Boards. The paper presents a reliability study named R1. The base of the study is a reliability experiment with 14 different solder alloys (13 lead free solders and a Sn63Pb alloy as a reference), six different surfaces, six different SMD-chips combined with three different pad layouts. A thermal shock reliability test was used. The times of failures were evaluated with the Weibull analysis followed by an analysis of variance.

Keywords: solder joints, solder alloy, reliability, Weibull analysis, optimisation

Introduction

The solder joint reliability is one important part for the reliability electronic products (including also SMT-Boards). Every customer demands a long individual life time of the used equipment. The experience with SnPb alloys over a long time lead to a broad expertise regarding reliability. The main goal of the project R1 is the comparison of common used 14 solder alloys. The project R1 is a joint work of the “Working Group Lead Free” in Germany.

Results

Various board finishes, chip sizes and three pad layouts complete the analysed factors. Table 1 gives an overview of the varied solder alloys, the analysed chip sizes and the used surface finishes. Additionally, three different substrate materials (CEM 1, IS 410 and IS 420) were used. The test board with 180 components has a daisy-chain for every chip size and for every pad layout. Every daisy-chain connects ten chips. Sample sections for metallography analysis were added. 52 combinations of the solder alloy, the surface finish and the substrate material were planned. 208 boards (four boards for every combination) were produced for the reliability test.

A base data set for the Weibull-analysis consists of 4x10 components with equal chip size, the same pad layout, the same alloy, the same surface finish and the same substrate material. 936 of such data sets exist for the whole experiment. The parameters for the reliability test are:

- thermal shock (-55...125 °C)
- 30 minutes hold time on every level
- < 10 s changing time

The daisy-chains were checked offline after 1000, 1500, 2000, 2500, 3250, 4000, 5000 and 6000 cycles. During the offline inspection, failed components were bridged.

The following figures show some typical results of the project. The maximum layout (pad size is larger than the common used size, green curve) has the best reliability result (see fig. 1). A minimum layout is therefore not recommended. The differences between the chip sizes (see. Figure 2) are well known. A ranking between the analysed (see fig. 3) alloys gives an orientation about the behavior of the alloys.

Table 1 Overview about the main varied factors

Alloy (1)	Alloy (2)	Surface type	Chip size
Sn-Ag3-Cu0,5	Sn-Ag4,1-Cu0,5	Chem. Sn	0201
Sn-Ag3,5	Sn-Bi57	NiAu	0402
Innolot	Sn-Bi57-Ag1	Chem. Ag	0603
Sn-Ag1,0-Cu1,2-NiGe	Sn-Ag4,1-Cu0,5-In4	HAL Sn	1206
Sn-Ag3,4-Bi4,8	Sn-Cu0,7-NiGe	HAL SnPb	2512
Sn-Ag3-Cu0,5-NiGe	Sn-Cu0,7-Ni0,05	OSP	MiniMelf
Sn-Zn8-Bi3	Sn-Pb36-Ag2		

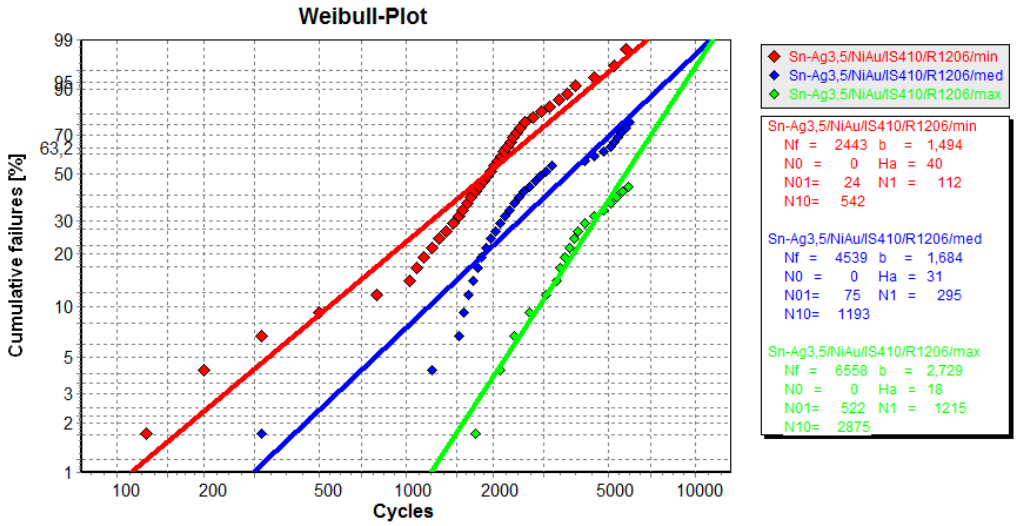

Fig.1: Comparison of the Weibull-Plots for three different layouts

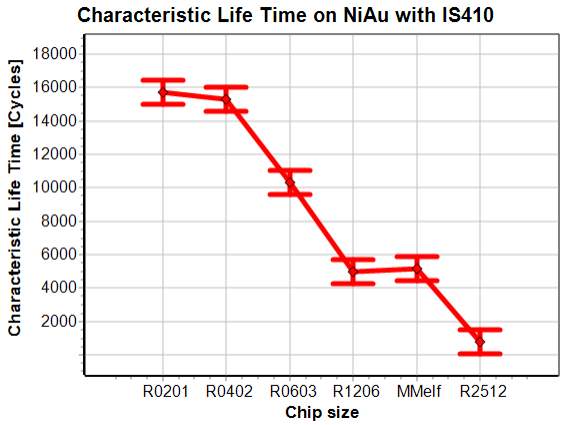

Fig. 2 Comparison of the chip sizes

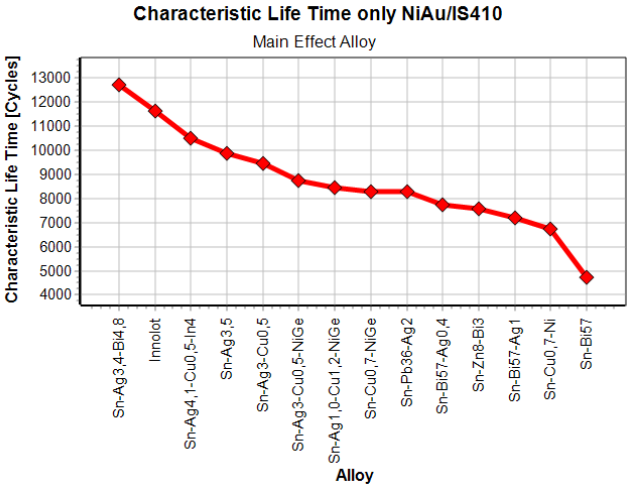

Fig. 3 Comparison of the alloys

Final remarks

The results of the project were put in a database (named R1-Expert). A comparison of the results of free selectable factors is possible. About 10000 metallography analysis are also available. The results will be completed with analysis of other quality characteristics, like the standoff, shear forces, voids and solder balls. This is important, because the only optimisation of the reliability can be a contradiction to the optimal setup for other characteristics.