Technical Paper

Fretting Performance of Lead Free Surface Finishes

Ned Corman
Tyco Electronics
Harrisburg, PA

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Abstract:
Fretting corrosion is a buildup of oxides on a tin rich surface finish. The oxides can lead to failure in tin platings as well as tin/lead plating systems. This work is centered on understanding the differences in performance between pure tin/lead plating and pure tin plating. The conclusions of this work indicate that pure tin, a replacement for tin/lead plating, performs equivalent to tin/lead for fretting corrosion performance. Further, alternative lead free surface finishes, such as gold and silver, are evaluated as well.

Introduction:
Fretting corrosion of tin lead contacts is a well documented phenomena.[1,2,3] The first two references are representative of the many technical papers which describe the fretting corrosion process. The third reference is a more recent reference that deals with lead free systems, but provides little detail on the performance of lead free platings.

Fretting corrosion can impact the performance of tin and tin/lead plated separable interconnects. Essentially, on initial mating, the oxide layer on a tin or tin lead plated surface is broken and metal to metal contact is established. However, if a small oscillatory relative motion (fretting motion) sliding or rocking at the interface occurs, the contact spot is reestablished with each motion. The freshly exposed tin oxidizes and the oxide layer continues to grow thicker as the motion repeats. Eventually, the oxide layer builds to a level which limits the metal to metal contact area and the contact resistance increases. Fretting motions typically range from less than 25 um (0.001 in) to a 100 um (0.004 in). Anti-fretting lubricants have been shown to be quite effective in controlling resistance increases for some applications[1].

Test Method:
A test apparatus, shown in Figure 1, forces a small displacement fretting motion at the sample interface. Only clean unlubricated samples were tested. A stepper motor is programmed to move the stage forward 25um (0.001in), dwell 10 seconds and then move back to the starting position. There are six stations on the stage. The interface at each station consists of a sample coupon and a 6mm (0.25 in) diameter formed rider. The rider is dead weight loaded to 100 g (0.1N) to provide a normal force that is representative of tin to tin separable interfaces. Precision bearings and a rigid balance beam design were utilized so that small motions of the stage would translate to an equal motion at the interface. Each station is wired for a four wire resistance measurement. A computer controlled data acquisition system was used to collect the data. This system consists of a Keithley 2010 Multimeter, a 7001 Switch Scanner and a computer running Keithley TestPoint software. The stepper motor is controlled using an Eason Stepper Motor Controller and Driver that is interfaced to the data acquisition system.

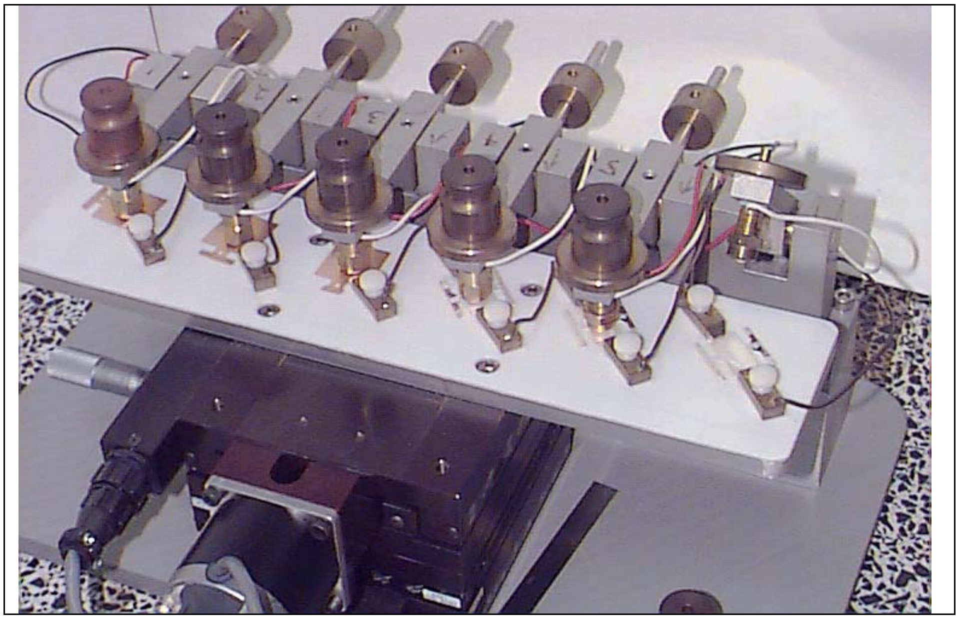

Figure 1. Fretting Apparatus

Materials:
The surface finishes evaluated in this study are shown in Table 2. The base metal used for each sample was C51100 (CuSn4) phosphor bronze.

Table 2. Surface finishes and thicknesses used in this study.

Finish	**Abbreviation**	**Thicknesses**
Cobalt hardened gold	CoAu	1.27 um gold over 1.27 um nickel
Silver	Ag	3.5 um silver over 1.27 um nickel
Bright tin/lead (93/7)	BtSnPb	3.75 um over 1.27 um nickel
Matte tin	Sn	2.5 um over 1.27 um nickel

The CoAu and BtSnPb samples were plated on a production plating line. While the Sn and Ag samples were beaker plated. All of the samples were ultrasonically cleaned for one minute in methylene chloride, rinsed with methanol and air dried.

Many of the test combinations were tested in a “like-to-like” manner. That is, both the coupon and rider had the same surface finish. For a few cases, matte tin plating was also mated to the other materials to look for interactions. Tin to gold matings, for example, are known to have poor fretting performance.

Results:
The results are shown in Figure 2. This figure shows all the materials and all the data points recorded. As expected the Sn and BtSnPb samples show significant resistance increases after 100 fretting cycles. This is as expected, since the apparatus forces a fretting motion at the interface.

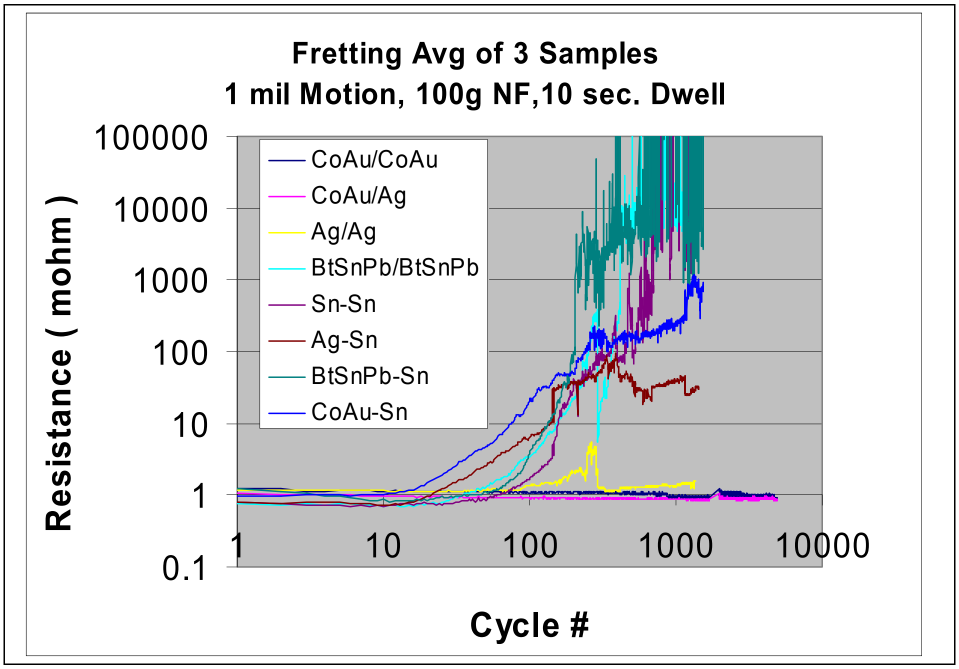

Figure 2, Complete Test Results for fretting performance.

Figures 3 and 4 show the trends in this data. Only selected data points (whole or ten's of cycle #) were plotted to declutter the graph. Like material (rider and flat) combinations are shown in Figure 3 and mixed combinations are shown in Figure 4.

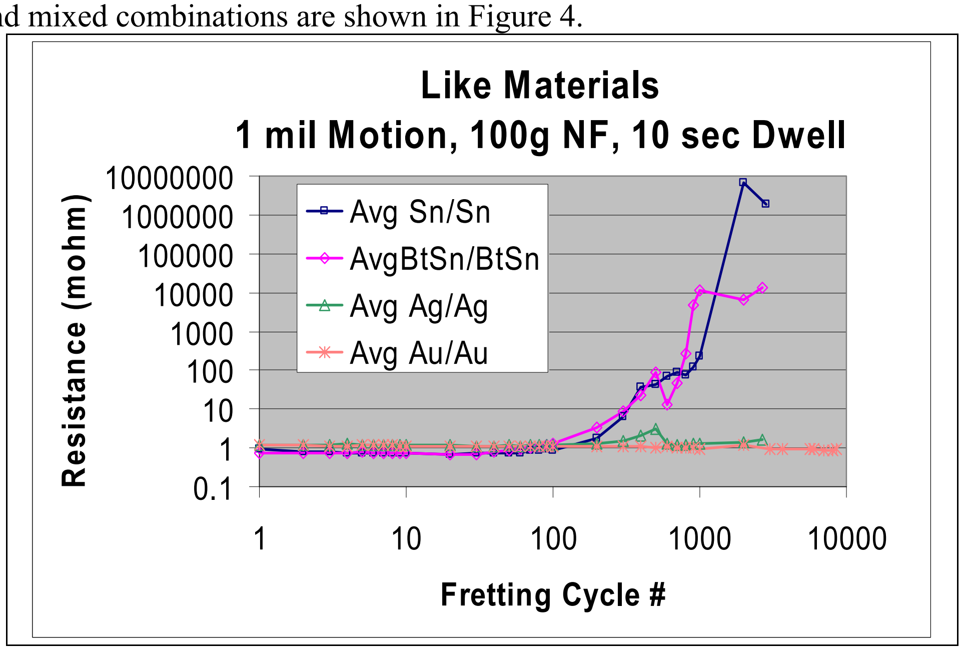

Figure 3. Rider and Flat Fretting Performance, Like on Like Plating

Figure 3 shows the fretting behavior of Sn and BtSnPb plating and the non-fretting behavior of the Ag and Au plating. The Ag shows a slight resistance instability, which is attributed to the relatively low normal force of 100g. 100g normal force is marginal for Ag contacts due to tarnish films which can grow on the surface of silver. However, silver is generally considered to be non-fretting[4].

Figure 4 shows the fretting behavior of combinations of plating with Sn and the non-fretting behavior of the combination of CoAu with Ag.

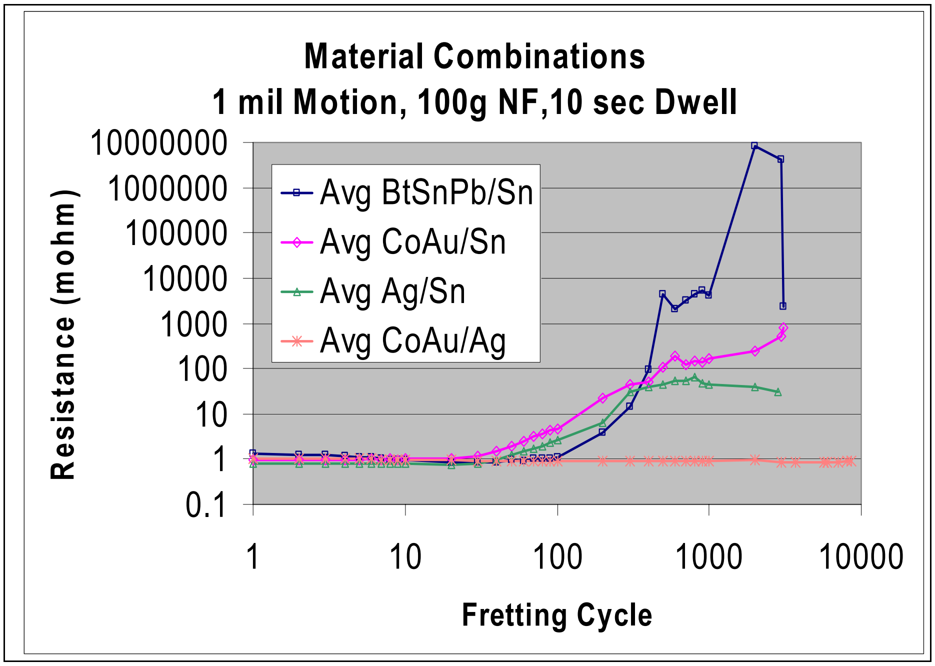

Figure 4, Rider and Flat Combinations of Plating

Conclusions:
Forced fretting on clean plated surfaces indicates that:

- Lead free tin is susceptible to fretting corrosion induced resistance increases. However, the performance was comparable to the fretting behavior of tin/lead surface finishes.
- In addition, combinations of bright tin lead, hard gold and silver each mated to lead free tin are also susceptible to fretting corrosion.
- Gold to gold, silver to silver and gold to silver interfaces are non-fretting.

These results are consistent with the present understanding of fretting corrosion in electrical contacts.

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[1] Fretting Corrosion in Electrical Contacts, E. M. Bock & J.H. Whitley, Proceedings of the Twentieth IEEE Holm Conference on Electrical Contacts, 1974
[2] Mateability of Tin to Gold, Palladium and Silver, E. M. Bock, AMP Engineering Note 141, 1989
[3] Effect of Fretting in Lead-Free Systems, D Gagnon, M Braunovic, Proceedings of the Fiftieth IEEE Holm Conference on Electrical Contacts, 2004
[4] Survey of Contact Fretting in Electrical Connectors, M Antler, Proceedings of the Twenty Ninth IEEE Holm Conference on Electrical Contacts. 1984, pg 6