

The determination of the thickness of the layers deposited on the electronic circuit boards through tribological methods

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Abstract. The purpose of the paper is to determinate the thickness of the copper layer deposit on the electronic circuit boards, the thickness of the soldering alloy SAC 307 (96.5%Sn/3.0%Ag/0.7%Cu) deposit on the copper-PCB assembly used in electronic industry and also to determinate the sliding length of the sphere on those materials. Slurry composed of water and SiC was used to reduce the testing time. For the experiment a CSEM Calowear equipment was used and the tested materials were the layer of FR4(flame retardant 4) with copper deposit and the soldering alloy SAC 307.

1. Introduction

It is known that the mechanical function is one of the most important three functions (electrical, thermal, mechanical) of the electronic assembly, according to the electronic technology theory. The mechanical integrity of the assembly is provided by this mechanical function. The subject of the present paper is related to the mechanical attachment of electronic assembly [1, 2].

As a printed circuit board (PCB) the FR4 material was used, which is a woven glass fabric with epoxy resin system. The lead-free solder paste SAC 307 deposited on the copper layer from the PCB layer was also used.

For the tribological test a CSEM Calowear equipment was used, that can provide a simple method to determine the coating thickness. A steel sphere with a diameter $d = 36.5\text{mm}$ was used for the experiment. The experiment consists in two tests with different time lengths performed in the presence of a slurry composed of water (250 ml) and silicon carbide (SiC- 5 g) that falls onto the contact region between the sphere and the samples and one test without the slurry composed of water and SiC.

The Calowear test (micro-abrasive test) is used for the quality evaluation of thick coatings.

It is important to know the thickness of the copper layer deposited on the PCB and also the thickness of the solder alloy paste deposited on the PCB that is covered with copper. It is also wanted to determine the sliding length of the sphere over the samples.

The real thickness of the copper layer deposited on the PCB, the real thickness of the solder alloy paste deposited and also the surface characteristics of the layer (at the interface between the rigid support and the free surface where the electronic components can be mounted) represent a quality element for the PCB [3].



The thickness of the copper layer on the PCB affects the behavior of the entire electrical circuit and it also affects the process of the layer adhesion. It is important to know the thickness of the copper layer in order to know the adhesion to the substrate and thus its mechanical behavior (shear resistance, behavior to vibrations, behavior in a variable thermal regime).

In the manufacturing technology for electric and electronic components a lot of measurements for the thickness of the copper layer are found. The values measured for commonly used thicknesses are: 17.5 μm , 25.5 μm , 35 μm , 71 μm , 105 μm . But in real situations we find that the real thickness of the copper layer has none of these values. From the analysis of the copper layer thickness through tribological methods (controlled wear), with or without abrasive suspension, it can be seen that the actual layer thickness sometimes differ significantly from those prescribed in the technological standards.

Any experimentally determined nominal adhesion parameter is a function of the elastic or plastic properties of the adhering material pair, interface conditions and loading conditions. The interface conditions include material structures, geometrical dimensions (thickness), solubility and amount of plastic deformation of each material in the adhering system, surface roughness, while the loading conditions include normal, shear or mixed loading, temperature, loading time, etc. [4, 5, 6, 7].

The present paper aims to determine through tribological methods the thickness of the layers used in electronics and to reduce the testing time through the controlled wear with slurry composed of water and SiC.

2. Experiment description

The CSEM Calowear Equipment used for the experiments is shown in the figure 1a. The configuration of the tests with a side view of the inclination of the plate is shown in figure 1b.

The measurement principle of the equipment is based on a rotating sphere made of bearing steel, with a diameter $d = 36.5$ mm, that presses the coating surface with a certain load. The values for the drive shaft number of revolutions are presented in table 1. The drive shaft radius is $R = 6.5$ mm and the length of the contact between the sphere and the drive shaft is $p = 10$ mm.

For the FR4 sample with a copper layer deposit the wear of the copper layer is very low (transfer phenomena on the ball) and the testing time for the determination of the thickness is high. In this case, the use of a slurry composed of water and SiC is proposed, thus the wear of the layer will be abrasive with rough particles in suspension (SiC in water).

During the tests conducted in a conventional dry regime for the FR4 sample with a copper layer deposit the controlled wear speed was very low and also a transfer of copper on the steel sphere could be observed (selective transfer). In this case the testing time was high and the wear phenomenon are influenced by selective transfer of the copper. Thus, for the layers containing copper it is recommended to adopt the solution of the controlled wear with slurry composed of water and SiC.

A consistent statistical result is considered to be composed of three identical tests. The statistic coefficient of variation for the wear of electronic layers in the CSEM testing equipment is 0.08. This coefficient is defined as the ratio between the standard deviation and the arithmetic mean and was determined by the previously experiments (ten identical experiments). For the mentioned statistic coefficient of variation, a consistent statistic result is comprised of the mean value of three identical tests.

Previous preliminary tests have shown that the friction force between the sphere and the layer varies significantly when the substrate is reached. Thus the determination of the thickness layer can be done, even after the complete wear, through optical measurements with a special magnifying glass without the removal of the sample.

The determination of the number of cycles and thus the sliding length at the damage of the layer appear was done first through a cycle of successive short tests (approximately 50 cycles). In the final part of the experiments was observed that it is need more than 1500 cycles to worn the layers. The decision concerning the number of cycles at which the layer was worn was taken through the

calculation of the arithmetic mean between the number of cycles at which the damage was observed and the number of from the last cycles where there was no damage.

During the tests, an abrasive slurry composed of water and SiC falls over the contact zone. When the sphere rotates against the sample, a wear spot appears. The dimensions of the wear spot was determined with the help of an Leica DCM 3D Dual Core optical equipment.

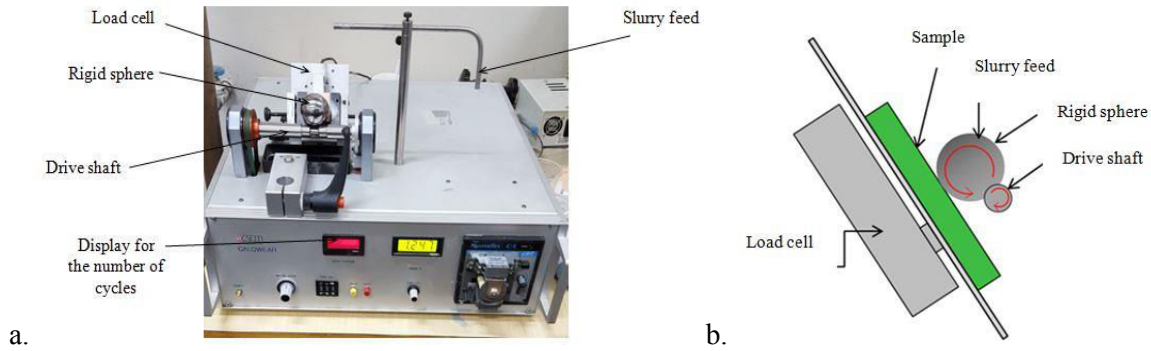


Figure 1 a. CSEM Calowear Equipment and b. The configuration of the tests

From the optical inspection of the wear spot we can measure the geometrical parameters a , b , x and y that are shown in figure 2 and knowing the sphere diameter d , with a simple equation 1 we can determine the thickness of the coating

$$h = \sqrt{r^2 - \frac{b^2}{4}} - \sqrt{r^2 - \frac{a^2}{4}} \approx \frac{x \cdot y}{2r} \quad (1)$$

where x , y , a and b are the geometrical parameters optically determined, r is the radius of the sphere.

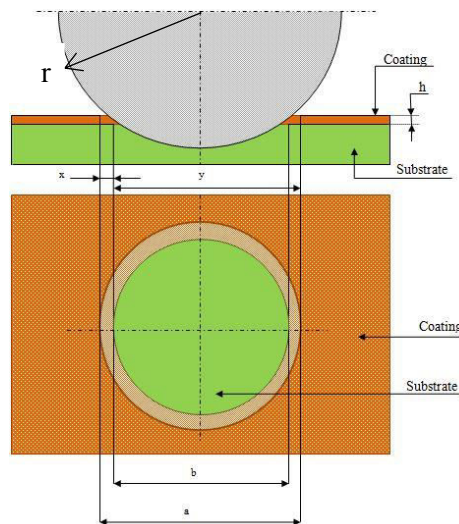


Figure 2. Calowear principle for the thickness determination of the covered material.

For the samples different time lengths in which the sphere slides on them were used. The first test (test 1) with the FR4 sample which has a copper layer deposited was done in the presence of the slurry composed of water and SiC with a working time of 1500 sec. The fixture of the sample is shown in figure 3a. Test number 2, done with a FR4 sample that has a copper layer and a soldering alloy SAC 307 deposited, was also done in the presence of the slurry composed of water and SiC. This test had a working time of 300 sec and the fixture is shown in figure 3b. Test number 3 was done for the same

FR4 sample that has a copper layer and a soldering alloy SAC 307 deposited, but without the presence of the slurry composed of water and SiC and with a working time of 1200 sec. Previous experiments were made on the same samples used in this experiment at different increasing time lengths.

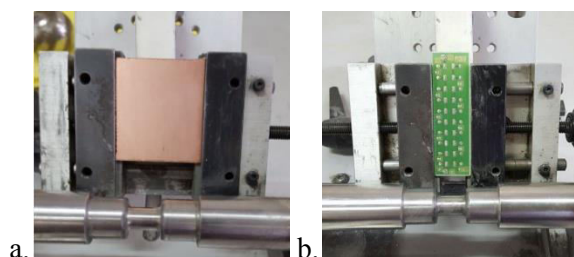


Figure 3. a. The sample FR4 with the copper layer deposited and b. the sample FR4 with the soldering alloy deposited on the copper layer.

The sliding length of the sphere is influenced by the diameter of the sphere and by the values of the elements from the contact between the sphere and the drive shaft shown in figure 4 [3].

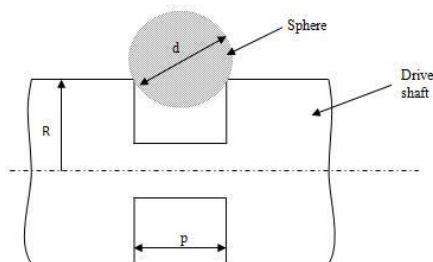


Figure 4. The contact between the sphere and the drive shaft.

The sliding length can be calculated using the equation 2 [3].

$$L = \frac{\pi \cdot R \cdot n \cdot d}{\sqrt{\left(\frac{d^2}{4} - \frac{p^2}{4}\right)}} \quad (2)$$

where d - sphere diameter; L - sliding length; n - drive shaft number of revolutions; R - drive shaft radius; p - length of the contact between the sphere and the drive shaft

3. Results

The present experimental results were processed in order to determine the sliding length using equation 2 and the mean values (three experiments) obtained are presented in table 1.

Table 1. Values of the sliding length

Test number	Sample	Time [s]	Number of cycles [rot]	Sliding length [mm]
1	FR4+Cu (SiC)	1500	8051	340960
2	FR4+Cu+SAC 307(SiC)	300	1614	68353
3	FR4+Cu+SAC 307 (without SiC)	1200	6436	272649

The images of the wear spot on the samples can be seen in figure 5. First the diameters a and b of the wear spot were measured and then with equation 1 the thickness of the copper layer and the

thickness of the soldering alloy SAC 307 deposited on the other sample were calculated. The results are presented in table 2.

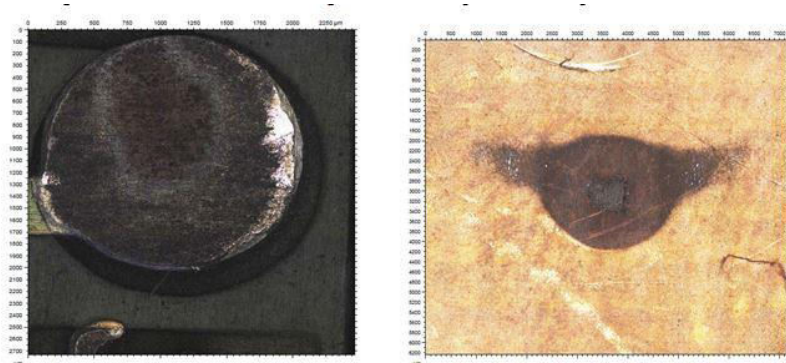


Figure 5. The optical inspection of the samples.

Table 2. Values of the thickness and wear parameter for the copper layer and for the soldering alloy SAC 307 layer

Sample	Layer	Thickness	Wear parameter
FR4+Cu	Copper	31 μm	9.09×10^{-11}
FR4+Cu+SAC 307	Soldering alloy SAC 307	2.6 μm	3.82×10^{-11}

The dimensionless wear parameter of layers (I_h) is considered that report of the thickness (h) to the sliding friction length (L) ($I_h = h / L$). This wear parameter is reported in table 2.

4. Conclusions

The real thickness of the layers is determined through controlled wear.

It is difficult to determine the thickness of the copper layer through the controlled adhesive wear in a conventional dry regime as a result of the selective transfer phenomenon of the copper on the steel sphere.

The thickness of other layers (without copper) can be determined even in a conventional dry friction regime.

The friction behavior of the layer, especially at the separation area with the rigid support, emphasizes the adhesion of the layer. This aspect will be detailed in a future paper.

The testing time is reduced significantly (approximately four times) when abrasive particles in suspension (SiC in water) are used.

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