Electrically Loaded Adhesive Bonds Formed on Different Surfaces

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Abstract: *Bonds of three types of electrically conductive adhesives with isotropic electrical conductivity have been formed on three types of surfaces – Cu; immerse Au and Sn (HAL). Epoxy resin types of adhesives with Ag flakes have been used. The bonds have been fabricated by assembly of jumpers. Two types of electrical load have been applied: DC current 1A and rectangular current pulses with the frequency of 500 Hz, mark-space ratio 1:1 and amplitude of 1A. The resistances, nonlinearity and noise of the bonds have been measured. It has been found that quality of the bonds on Sn surface finish is unacceptable through instability and level of measured parameters. The resistances and nonlinearity of the bonds formed on Au surface finish have beenhigher in comparison with those measured on Cu pads; noise have been comparable. Both types of the current load have caused low changes of all parameters tested.*

1. INTRODUCTION

Electrically conductive adhesives are materials with growing significance in electronics packaging. Adhesives are used for bonding of different materials and types of surface finishes. It can influence electrical as well as mechanical properties of the bonds [1].

Surface finish and surface oxide films on pads influence quality of adhesive bonds more than quality of the soldered bonds. Fluxes used in a soldering process cleanse oxides from pads and make better joining between solder and a pad possible.

Electrically conductive adhesives are filled with electrically conductive particles. The particles of filler are usually Ag balls, Ag flakes, or a combination of both these types of particles [2], [3], [4]. Other types of conductive particles are plastic balls covered with different types of conductive films; with Ag or Au film the most often. Some types of these particles have the conductive film covered with a very thin insulating film, which intercepts to contacts among the particles in x-y plane. The adhesive bonding process, contrary to the soldering process, uses no fluxes, which would improve quality of the adhesive bonds. Therefore material and surface finish of joined surfaces has significantly higher influence on final electrical and mechanical quality of adhesive bonds than on quality of soldered ones.

However, on the other hand, adhesive bonding has one advantage in comparison with soldering [5]. Adhesives shrink after curing. Therefore the volume of adhesive bond decreases, but the volume of the filler does not change. The contacts among the filler particles improve and also the contacts among the filler particles and the surface of the pad improve. The filler particles are pressed to the pad surface and a possible oxide film covering the pad or the contact surface is broken. Therefore quality of the bond improves by curing.

It is very good known that mobility of Ag ions is high and that their migration can cause bridging between near contacts if there is a DC voltage connected between them. Such the bridge can cause the breakdown of equipment [6]. Electrically conductive adhesives are mostly filled with Ag balls or flakes. By this reason it can be assumed that the properties of electrically conductive adhesive bonds can also be sensitive to the DC current or current pulses flowing through the adhesive bonds [7]. Such the property of the adhesive bonds would limit their use in some applications.

The goal of the work has been as follows: to find out how material and surface finish of surfaces joined by the use of electrically conductive adhesive can influence the electrical properties of adhesive bonds and to find out whether the DC current of a high level and rectangular current pulses influence electrical properties of the adhesive bonds substantially.

2. EXPERIMENTAL

2.1 Specimens under Test

Isotropic electrically conductive adhesives (two of a one-component type, one of a two-component type) based on epoxy resin matrix with Ag filler have been used for fabrication of the adhesive bonds. The types of adhesives used and their basic properties are shown in Tab. 1

Tab. 1 Types of adhesives used for experiment

Eco Solder AX 20	
Formulation	Phenolic-epoxy rezin
Curing temperature	200 °C
Curing time	6 min
Resistivity	3,0 to 3,5 . 10^{-6} Ωm
Number of components	1
Elpox ER 55 MN	
Formulation	Phenolic-epoxy rezin
Curing temperature	180 °C
Curing time	6 min
Resistivity	4,0 to 7,5 . 10^{-5} Ωm
Number of components	1
Elpox 656 S	
Formulation	Phenolic-epoxy rezin
Curing temperature	180 °C
Curing time	9 min
Resistivity	7,0 to 10,0 . 10^{-7} Ωm
Number of components	2

The bonds have been formed by adhesive assembly of jumpers on pads of a test board. The surface finishes of the pads have been Cu; immerse Au (2 μm) and Sn (HAL).

2.2 Measurement of the Electrical Resistance, Noise and Nonlinearity of the Bonds

The bonds have been loaded with the DC current 1A or with rectangular current pulses having the amplitude of 1A. The mark-space ratio of the pulses has been 1:1, the frequency 500 Hz. The load has been applied for 50 hours. It is necessary to remark that the DC current load has caused increase of the temperature of the bonds by 55 °C, the pulse load has increased their temperature by 37 °C. The resistance has been measured in a four-point arrangement using an impedance-meter HP 4284A, nonlinearity using a spectral analyzer HP 8560 and noise using a lock-in amplifier PAR 124 A [8].

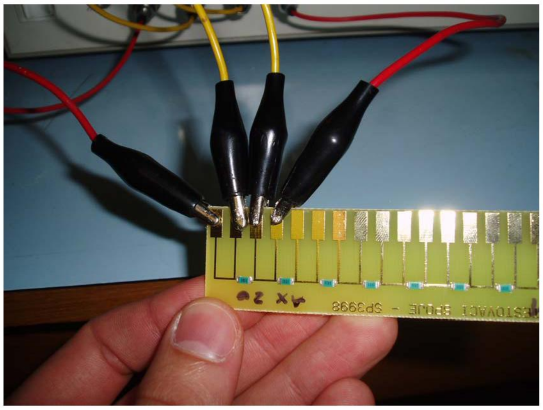

Fig. 1 Test board and the four-point measurement of the bond resistances

The schematic diagram for the measurement of noise is shown in Fig. 2.

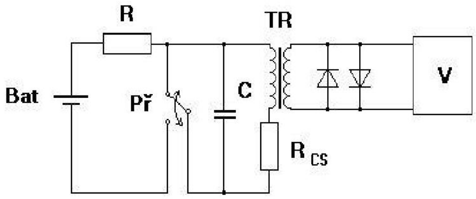

Fig. 2 Schematic diagram of noise measurement, V is a lock-in amplifier, R is a measured bond

The schematic diagram of nonlinearity of the current vs. voltage characteristic measurement is shown in Fig. 3.

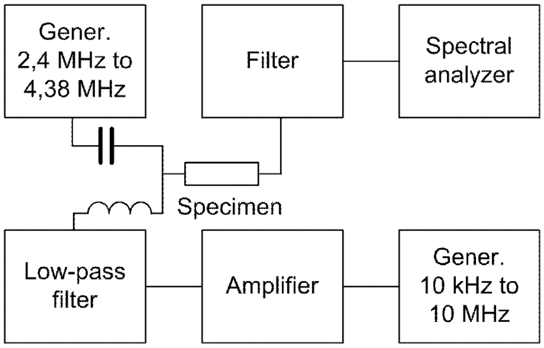

Fig. 3 Schematic diagram of the nonlinearity measurement

By the reason that the temperature of the bonds has risen during their current load with the DC current or with the current pulses, the results of all measurements have been calculated as differences. The process of calculation of the bond resistances, noise and nonlinearity has been carried out in following steps:

1. The jumper assembled with adhesive has been loaded with the DC current (current pulses) and the resistance, noise and nonlinearity of a combinations adhesive bond – jumper – adhesive bond have been measured. The temperature of the adhesive bonds has also been measured. An infrared thermometer and a Cu-Constantan thermocouple have been used for this measurement.
2. The resistance, noise and nonlinearity of the individual jumpers at the normal temperature and at the temperatures, which have been measured on the adhesive bonds loaded with the current and current pulses, have been measured.
3. The specimens with the jumpers assembled with adhesive have been heated in an oven and the resistance, noise and nonlinearity of the combination adhesive bond – jumper – adhesive bond have been measured at the same temperatures, which have been measured on the adhesive bonds loaded with the current and current pulses.
4. The values of the bond resistances at the normal as well as elevated temperature have been calculated by subtraction of the jumper resistance measured at the normal or elevated temperature from the resistance of the combination adhesive bond – jumper – adhesive bond measured at the same temperature.
5. The values of the bond noise at the normal as well as elevated temperature have been calculated by subtraction of the jumper noise voltage measured at the normal or elevated temperature from the noise voltage of the combination adhesive bond – jumper – adhesive bond measured at the same temperature.
6. The values of the bond nonlinearity at the normal as well as elevated temperature have been calculated by subtraction of the jumper nonlinearity voltage measured at the normal or elevated temperature from the nonlinearity voltage of the combination adhesive bond – jumper – adhesive bond measured at the same temperature.
7. Then the change of the bond resistance, noise and nonlinearity caused by the current or the current pulses has been calculated as a difference between the value of every parameter measured under the load of the bond and the value of this parameter measured at the same temperature without the electrical load.

3. RESULTS OF THE MEASUREMENTS

The results of the measurements are shown in Fig. 4 to Fig. 9. It has been found that the changes of the bonds resistances caused by the current load and current pulses are low for both types of surface finishes. The bonds resistance is lower for the Cu finish.

Noise depends on the electrical load of the bonds slightly. It has been found that the noise voltage increases for adhesive AX20 if the bonds are loaded with the DC current and current pulses, whereas this voltage decreases for adhesive 656 S in dependence on the electrical load. The bonds on Cu pads have lower noise than the bonds on Au pads.

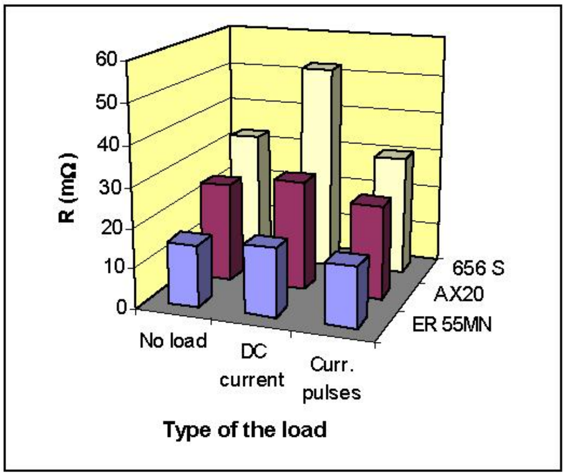

Fig. 4 Changes of the bonds resistances caused with the DC current and current pulses. Finish of the pads: Au

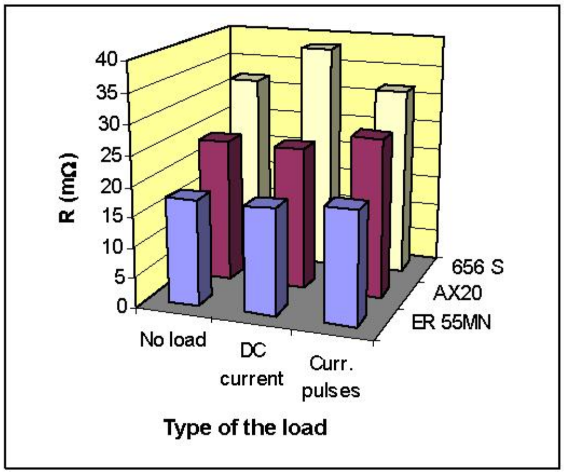

Fig. 5 Changes of the bonds resistances caused with the DC current and current pulses. Finish of the pads: Cu

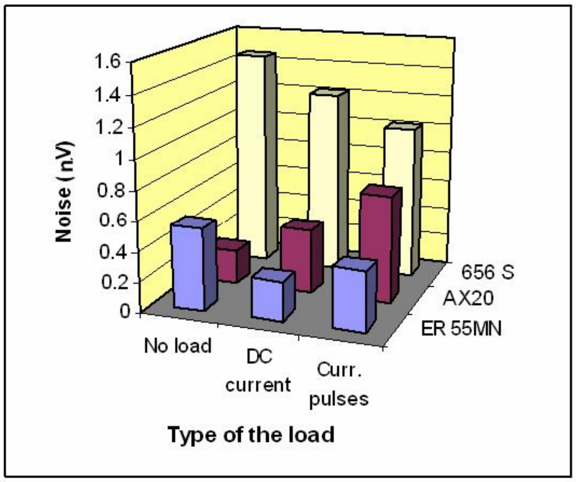

Fig. 6 Noise of the bonds. Finish of the pads: Au

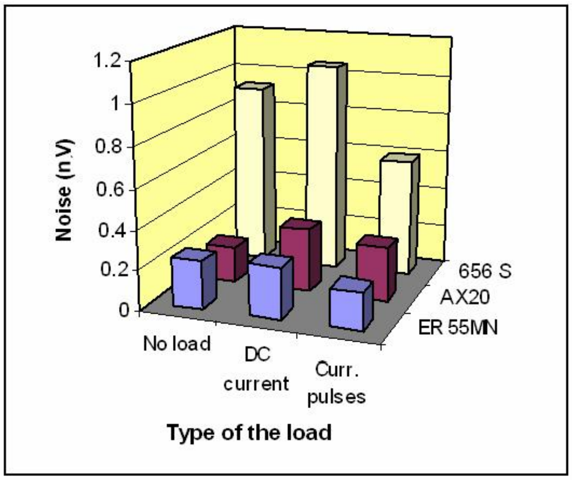

Fig. 7 Noise of the bonds. Finish of the pads: Cu

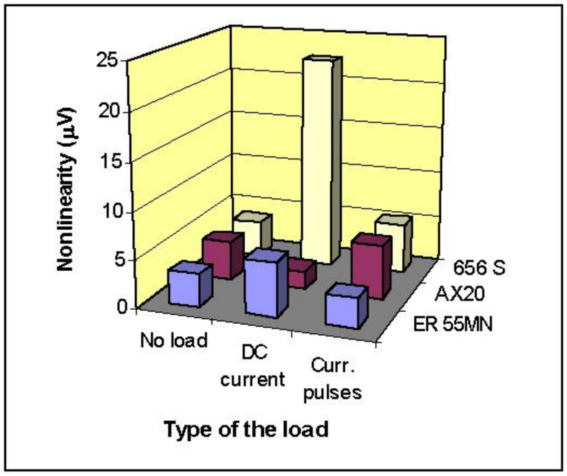

Fig. 8 Nonlinearity of the current vs. voltage characteristic of the bonds. Finish of the pads: Au

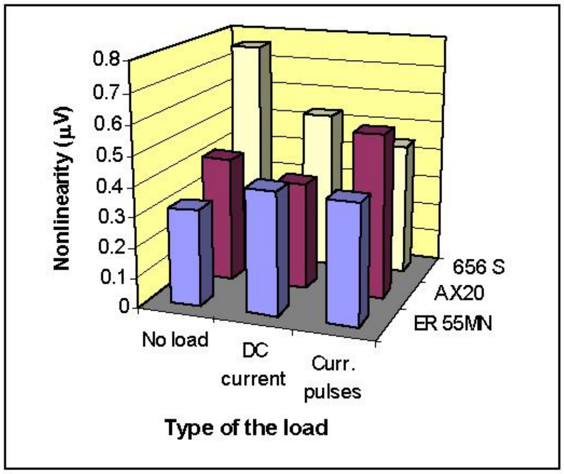

Fig. 9 Nonlinearity of the current vs. voltage characteristic of the bonds. Finish of the pads: Cu

The noise level is very low. Therefore the noise voltage of more bonds (of 14 usually) connected in series has been measured and the noise voltage of one bond has been calculated. Different combinations of individual bonds have been measured in series to find out whether the final noise voltage of the bonds joined in series is not caused by one or two bonds dominantly.

It has been found that nonlinearity of the bonds is influenced with the DC current and current pulses slightly only. The bonds formed on the pads with the Au finish have had lower level of nonlinearity in comparison with the bonds formed on the Cu pads.

Quality of the bonds formed on the pads with the Sn surface finis has been very low and the results have not been repeatable.

CONCLUSIONS

The adhesive bonds formed of three types of electrically conductive adhesives with isotropic electrical conductivity on three different types of the surface finishes have been investigated. The bonds have been loaded with the DC current and current pulses.

It has been found that the Cu finish is better from the viewpoint of all measured electrical parameters. Nonlinearity of the bonds formed on the Cu pads has been substantially lower than nonlinearity of the bonds prepared on the Au pads.

The changes caused with the electrical load have been low. It means that both the phenolic-epoxy resin and epoxy resin do not make migration of Ag ions possible. Therefore almost no changes of electrical parameters have been observed after the electrical load although the DC current density and the density of the pulse current have been so high that they have caused heating of the bonds.

The results of the measurements of the bonds formed on the pads with the Sn finish have been not repeatable. The values of all measured parameters have been sizes higher in comparison with them, which have been measured on the bonds formed on the Cu or Ag finishes. Therefore the Sn surface finish is not usable for adhesive assembly.

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