THE CONDUCTIVE ADHESIVE JOINS UNDER THERMAL SHOCKS

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Abstract

The work is focused on joins realised by electrically conductive adhesives. Electrically conductive adhesives are used as alternative to soldering technology. Lower curing temperature is main advantage of adhesives. But electrical and mechanical parameters are worse than for solders. Research adhesives with added nanoparticles are carried out to improvement of electrical properties. The influence of thermal shocks on properties of joins realized by electrically conductive adhesives were analyzed. The temperature during thermal ageing is changed from room temperature to temperature below freezing point. Electrical resistance and non-linearity of current voltage characteristic were measured. Mechanical strength was measured too.

Keywords: Electrically conductive adhesive, accelerated ageing, non-linearity of I-V characteristic

1. INTRODUCTION

Electrically conductive adhesives are used as alternative to soldering for realization of electrically conductive joins. Electrically conductive join do not be created by method of soldering in some cases. An example is conductive joins in LCD displays where the jointed components can be damaged by high temperature during soldering process. Curing temperature of adhesive is much lower than melting point of solder. Curing temperature of adhesives is lower than 200°C. Two component adhesives cannot be cured at enhanced temperature. There is possible to cure adhesive at room temperature.

Electrically conductive adhesives with functional silver component are most widely used. Electrically conductive adhesives have worse electrical and mechanical properties in comparison with solder generally. Therefore the great attention is paid to investigation of electrically conductive adhesives at the present time. Experiments with adhesives with addition of nanoparticles are carried out. Aim of experiments is improvement of properties of joins realised by electrically conductive adhesives.

The accelerated ageing testing is used for estimation of lifetime and reliability of electrical devices. Accelerated ageing at enhanced temperature is applied most frequently. But electrical devices are exposed to low temperatures under freezing point too. Electrical devices in automobile are typical examples of such devices. Changes of temperatures during operating time can cause and propagate the defect in conductive joins. That defect influence electrical and mechanical properties of joins.

2. SAMPLES PREPARATION

An example of tested sample is shown in fig 1. PCB for tested samples was designed for joining of SMT resistors by electrically conductive adhesive. Material of PCB is FR4 with cooper layer. The resistors 0R0 (resistor with “zero” resistance) were used. Real value of resistance is around 16 mΩ. Seven resistors are joined to one PCB.

Fig. 1 PCB with SMD resistors connected by adhesive
Electrically conductive adhesives were deposited to PCB by device for inject deposition. Used device enable the adjusting of required quantity of adhesives by regulation of pressure and time of acting pressure on cartage with adhesive. Detail of adhesive join in cross section is shown in fig. 2.

Samples were subjected to temperature cycling. One cycle include the exposition of samples at low temperature (190°C) during 5 second and stabilization at room temperature during 10 minutes. That process was repeated cyclically. Temperature was changed between two values with steep gradient.

Four types of electrically conductive adhesives were tested. All adhesives were isotropic. Producer of adhesives is AMEPOX Company. One of adhesives was double component adhesive and other three were single component adhesives. Elpox ER 55MN is single component, electrically conductive, silver filled, epoxy-phenolic base resin adhesive. Adhesive is cured 20 minutes at 150°C. ECO SOLDER AX 20 is single component electrically conductive adhesive filled by silver. This adhesive is designed for replacement of traditionally tin-lead solder pastes. Adhesive is cured at 150°C and have extremely short curing time (5 – 10 minutes). ELECTRON ER 48 is single component, electrically conductive, silver filled lacquer. Lacquer is cured 30 minutes at 140°C. ELPOX 656 S is double components, silver filled epoxy conductive adhesive. Adhesive is cured 60 minutes at 140°C.

3. MEASURED PARAMETERS AND THEIR MEASUREMENT

3.1 Electrical resistance

Measurement of electrical resistance is relatively simple and quick method for testing of quality of electrical joins. Resistance of joins with electrically conductive adhesives is low value in order of tens mΩ. For measurement of such low values is necessary to use of four point method. Outer two terminals are current terminals and inner two are voltage terminals. Samples were feed by AC signal with frequency of 1 kHz. The level of feeding signal must be low to prevent of heating of electrical join.

3.2 Non-linearity of current voltage characteristic

Electrically conductive adhesive is material with non homogeneous structure. Conductive particles (silver for example) are dispersed in isolative matrix. Thus, mechanism of conductivity in such structure is complicated. Distortion of feeding AC sinusoidal signal arises by passing through the non homogeneous structure. Distorted signal contain non zero higher harmonics.
The method of measurement of intermodulation distortion was used for evaluation of non linearity of I-V characteristic. Block diagram of method is shown in fig. 3. If tested electrical component is connected to two generators with frequencies $f_1$ and $f_2$, intermodulation signal is generated by non linearity of component. Frequency of that signal is given as:

$$f = n \cdot f_1 + m \cdot f_2$$

(1)

where frequency $f_1 = 150$ kHz, frequency $f_2$ is ranged from 4.1061 MHz to 4.1066 MHz, $n$ and $m$ are positive integral numbers representing multiplies of frequencies and $n = 2$ and $m = 1$. Intermodulation product of third order of harmonics of voltage was evaluated by spectrum analyzer.

### 3.3 Mechanical strength

PCB and joined electrical component can have different coefficient of linear expansion. Mechanical stress is arisen at temperature changes. Mechanical stress leads to cracks. The compressive force necessary to pull off of SMD resistors from PCB was measured.

Principle of measurement is shown in fig. 4. Increasing defined force is pushed on resistor until do not separated from PCB. Samples for mechanical testing were special modification. Gaps on PCB under the resistor are drilled for passing of spine of measuring device.

### 4. RESULT DISCUSSION

#### 4.1 Electrical resistance

Electrical resistance was measured for each join between PCB and resistor separately. That means the 14 measurement was realized on one samples PCB with 7 resistors. Dependence of resistance on number of temperature cycles for all measured adhesives is shown in fig. 5. Values for adhesives ER 55MN and ER 48 are small in comparison with others. Graph for detailed analysis of adhesives with low resistance is shown in fig. 6.
Dependencies of resistance have increasing tendency according the expectation. Difference is in gradient of decreasing of dependence for separate adhesives. Lowest decreasing of values of resistance during temperature cycling we can observe at adhesive ER 55MN. Value of resistance change about 27% after 100 cycles compared to beginning of cycling. Highest change of resistance is at double component adhesive ER 656 S. Value of resistance after 100 cycles is approximately 25 times higher than value at the beginning of cycling.

4.2 Non-linearity of current voltage characteristic

Intermodulation distortion was measured not for each join separately but for system of two adhesives joins, SMD resistor and cooper path on PCB. The dependence of non linearity of I-V characteristic expressed in voltage of third harmonics on temperature cycling is shown in fig. 7. Values of voltage for adhesives ER 48 and ER 55MN are shown in more fine scale in fig. 8. Values for ER 55MN are multiply by 10 in that graph.

![Fig. 7 Dependence of third harmonics voltage on temperature cycling](image1)

![Fig. 8 Detail of dependence of third harmonics voltage on temperature cycling for small values](image2)

Increasing tendency of dependence is expected. Such tendency is possible to observe for adhesive ER 48. Very low value of voltage is at the start of cycling. Rapid increasing come after first 20 cycles. Values of voltage for adhesives ER 55MN and AX 20 are increased first and then are stabilized after certain number of cycles. Value of voltage after approximately 50 cycles is higher 3 times (ER 55MN) and 4.5 times (AX 20) compared to beginning of cycling. Values changed minimally with next cycling. Specific behavior has adhesive ER 656 S. Value of voltage rapidly increase during first 40 (almost 300 times). After next cycles the values are decreasing. Value of voltage after 100 cycles is reached almost starting value.

4.3 Mechanical strength

The dependence of force necessary to pull off of resistor on number of temperature cycling is shown in fig. 9. Force is decreased with higher numbers of cycles. Force is almost same at beginning of cycling for all three single component adhesives. Values of

![Fig. 9 Dependence of mechanical force on temperature cycling](image3)
force at beginning is ranged between 10 N and 15 N. More than double value of force is necessary to separate of resistor connected to PCB by double component adhesive ER 656 S at start of cycling. Force is decreased about to half value after first 20 cycles and then is changed not very dramatically. Small changes of force with number of cycles we can observe for adhesives AX 20 and ER 55MN. Big decreasing of force with increased number of cycles is occurred for adhesive ER 48. Resistor was pull off by weight of spine soon after beginning of cycling.

5. CONCLUSION

The behaviour of adhesives during temperature cycling does not same at all tested electrically conductive adhesives as indicate analysis of results. That fact is possible to observe at results from measurement of non linearity of I-V characteristic. Method of non linearity measurement is very sensitive to structural changes in material. Temperature cycling at low temperature is leading to stabilisation of structure after few cycles probably. It indicate the result of non linearity for adhesive AX 20 and ER 55MN especially. Specific behaviour indicates the results for double component adhesive ER 656 S.

Mechanical test for force measurement is destructive method in comparison with measurement resistance and non linearity. Thus new samples are necessary for each measurement. That causes the certain fluctuation of values of force in dependence on temperature cycling probably.

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LITERATURE


