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Climatic testing of PCB interconnections made by electrically conductive adhesives

Ryszard Kisiel[1], Janusz Borecki[2], Jan Felba[3], Andrzej Moscicki[4]

[1]Warsaw University of Technology, Institute of Microelectronics and Optoelectronics
00-662 Warsaw, Koszykowa 75, Poland
[2]Tele and Radio Research Institute, Centre for Advanced Technology of Electronic Interconnections
03-450 Warsaw, Ratuszowa 11, Poland
[3]Wroclaw University of Technology, Faculty of Microsystem Electronics and Photonics
53-439 Wroclaw, Janiszewskiego 11/17, Poland
[4]Amepox Microelectronics
90-268 Lodz, Jaracza 6, Poland

Abstract: The aim of the work is to investigate the resistance stability of through holes filled by electrically conductive adhesives. The double sided PCB thickness 0.6 mm, with the holes diameters: 0.3 mm, 0.5 mm and 0.8 mm were filled by new series of electrically conductive adhesives. The new adhesives have the filler in form of mixture of Ag flakes micrometer size with Ag nanopowders. The influence of adhesive way of applying on fill resistance as well as fill resistance stability during climatic tests was investigated. Holes were filled by adhesive in two ways: by classical stencil printing and by printing with vacuum assistance. Holes filled by classical way have lower fill resistance than holes filled with vacuum assistance. Two climatic tests were performed: storage test (1000h & 125°C) and thermal cycling test (-40°C - +125°C & 1000 cycles). The fill resistance changes in both tests are not bigger than 10%. Such results are satisfactory for practical application based on polymer materials.

Key words: conductive adhesives, hole filling, climatic tests

1. INTRODUCTION

Since invention of printed circuit technology by Dr Paul Eisner in 1936, several methods and processes have been developed for manufacturing more useful PCBs. In the last decade the double sided and multilayer boards were the most popular. The double-sided boards can be classified into two categories: with and without through-hole metallization. The category of through-hole metallization can be divided into two types: plated through-hole (PTH) and silver filled through-hole (SFTH) [1]. The plated through-hole production started from procedure of catalyse palladium deposition followed by electroless copper plating. Then, thicker plating is done by means of galvanic plating. During such processes the environmentally hazardous chemicals are used. So, the new, more environmentally friendly solutions are searched.

Contrary, SFTH boards are usually made of paper phenolic materials or composite epoxy paper. Double-sided copper-clad materials are etched to form conductor patterns on both sides of the panel; next holes are formed by drilling. Then the panel is screened with silver-filled conductive paste. Since SFTH boards have a relatively high electrical resistance compared to PTH boards, the applications of SFTH boards is limited. However, because of their economic advantage, their application has spread to high-volume, low cost products such as audio equipment, floppy disk controllers, car radio, etc. The SFTH process is environmentally more friendly than plated through-hole process. Additionally, the cost of equipment is very low, and equipment is often available from PCB producer. Even through the technology to produce STH boards is known, there are some elements that must be improved. The silver-filled paste needs to be improved for the final product reliability. Our research team studied the using of polymer materials for through hole and blind vias filling in PCBs. In our experiments the thermosetting, one-component, silver filled epoxy conductive adhesives were applied [2]. The adhesives contain the silver filler in the form of flakes with average dimension of few micrometers. The results of experiments were presented in paper [3]. It was found that it is possible to obtain the fill resistance in the range of 50 ÷ 60 mΩ and 30 ÷ 40 mΩ for through hole diameters 0.5 and 0.8 mm for contact pads with Ni/Au metallization, respectively. The fill resistance for holes diameter 0.5 mm was more stable after climatic test than fill resistance in holes diameter 0.8 mm. It was found that the adhesive shrinkage in bigger hole was responsible for such results. In that case, the adhesive cracks near the hole edge. Such cracks were responsible for worse results. So it was decided to change the way of adhesive print. After the first print the adhesive was dried. Small cracking was observed near hole edge. So, the second adhesive print was done on first print with cracking. The adhesive was dried again and curried. No cracks on hole edges were observed.

To decrease adhesive resistivity and increase its compatibility to cover the hole edge, the silver nanopowder was added to adhesive. These two actions: double adhesive print and applying new adhesive with Ag nanopowders significantly reduces the hole fill resistance to 25 ÷ 30 mΩ for holes 0.5 mm diameter and to 15 ÷ 20 mΩ for holes 0.8 mm. [4].

The aim of the paper is to investigate the fill resistance changes of through holes filled by new series of adhesives where the adhesive filler is the mixture of silver flakes and nanopowders. The holes were filled by adhesive in two ways: by classical double stencil printing with adhesive drying between prints and by adhesive printing with vacuum assistance. The adhesive print with vacuum assistance permits to obtain holes covered by adhesive on hole walls with empty space in the hole middle. No cracks were observed on hole edge. The fill resistances changes during climatic tests of holes filled with adhesives using two described procedures were investigated and compared.

2. TEST SAMPLES AND MEASURING TECHNIQUES

The test samples for through hole filling were manufactured from double-sided FR-4 laminate, 0.6 mm thick, with Cu layer 18 μm, with contact pads electroplated by Ni/Au. The holes were mechanically drilled. In each test sample was 40 holes diameter 0.3 mm, 40 holes diameter 0.5 mm and 40 holes diameter 0.8 mm. The holes in test samples were adhesive filled by one from two procedures described previously. Next, the test samples was dried (80°C & 30 min) and cured (165°C & 15 min).

The quality of adhesive filling in through holes was estimated by individual fill resistance measurements. The individual fill resistance consists of the adhesive fill resistance and contact resistance between adhesive and Ni/Au pads metallization. Keithley 2001 multimeter with four wires option was used for resistance measurements.

Two types of climatic tests were used in investigations. The high temperature storage test, where test samples was storage in temperature 125°C during 1000 h in air. The thermal shock tests were performed in climatic chamber -40°C ÷ +125°C, 1000 cycles, one cycle -40°C 0.5 h and 0.5 h in the temperature +125°C, quick temperature zone changes.

3. TEST SAMPLES MEASUREMENTS AND COMPARISION

Tab.1 The comparison of fill resistance made by classical way and with vacuum assistance

N=160	R [mΩ] of holes diameters		
	0.3 mm	0.5 mm	0.8 mm
Classical way	23 ± 2	17 ± 2	11 ± 1
Vacuum assistance	29 ± 5	50 ± 16	28 ± 10

In the first series of experiments the fill resistance of through holes made by different way was compared. The results were shown in Tab.1. The fill resistance of through holes filled in classical way with double print and dried have lower and more repeatable fill resistance than holes filled with vacuum assistance. Uneven adhesive layer on hole walls causes higher changes of hole fill resistance deposited with vacuum assistance. Adhesive thickness depends on the adhesive viscosity, and level of vacuum during adhesive printing. It is difficult to obtain the same level of vacuum for different hole diameter using the homemade pressure equipment. On the other hand in previous investigation it was find that fill resistance for tube shape is more stable than for full fill [3]. To verify previous investigation new series of experiment with vacuum assistance was done. The tube shape fill in holes are more repeatable and no cracks on hole edge were observed.

4. RESULTS OF STORAGE TESTS

The following samples were selected for storage tests: made by classical way with full fill of holes and made with vacuum assistance, the hole fill has tube shape. The fill resistance was measured after sample preparation and after some time intervals up to 1000h. The results of fill resistance measurements for full and tube shape fill were collected in Tab.2 and Tab.3. It is interesting to notice that fill resistance decreases with storage time. It can be connected with adhesive curing process, which was probably not completely finished before the storage test starts.

Tab.2 Changes of average through hole fill resistance during storage test 125°C 1000 h, adhesive Elpox EXP 8.1, full fill

N=160	Average through hole fill resistance R ± σ [mΩ]		
Diameter	0.30 mm	0.50 mm	0.80 mm
0 h	23 ± 2	17 ± 2	11 ± 1
48 h	23 ± 2	16 ± 2	11 ± 2
168 h	22 ± 2	15 ± 3	11 ± 2
250 h	22 ± 2	16 ± 2	11 ± 2
500 h	22 ± 2	16 ± 2	11 ± 2
1000 h	21 ± 2	16 ± 2	11 ± 2±
ΔR/R	-9%	-6%	0%

Tab.3 Average through hole fill resistance changes during storage test 125°C 1000 h, adhesive Elpox EXP 8.1, tube shape fill, made with vacuum assistance

N=160	Average through hole fill resistance R ± σ [mΩ]		
Diameter	0.30 mm	0.50 mm	0.80 mm
0 h	29 ± 5	50 ± 16	28 ± 10
48 h	28 ± 4	50 ± 16	28 ± 10
168 h	28 ± 4	48 ± 16	27 ± 10
250 h	27 ± 4	48 ± 16	26 ± 10
500 h	27 ± 4	46 ± 16	26 ± 10
1000 h	26 ± 4	44 ± 16	25 ± 10
ΔR/R	-10%	-12%	-11%

Tab.4 Average through hole fill resistance changes during thermal shock -40°C ÷ +125°C, adhesive Elpox EXP 8.1, full hole fill

N=80	Average through hole fill resistance R ± σ [mΩ]		
Diameter	0.30 mm	0.50 mm	0.80 mm
0 cycles	29 ± 6	17 ± 2	11 ± 2
200 cycles	27 ± 7	16 ± 2	11 ± 2
400 cycles	27 ± 6	16 ± 3	11 ± 2
600 cycles	26 ± 7	16 ± 3	11 ± 2
862 cycles	27 ± 7	17 ± 3	11 ± 3

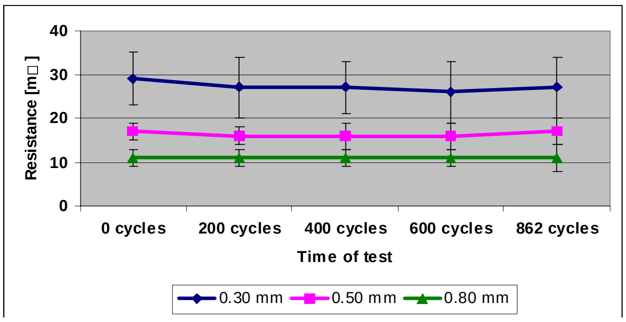

Fig.1 Full fill resistance changes during thermal shock tests

The results of thermal shock tests for full fill were shown in Tab.4 and graphically presented in Fig.1. Similarly as for storage tests the fill resistance decrease with time, particularly for holes with smaller diameter. The resistance changes are not significant, better results were obtained for holes with bigger hole diasmeters.

Tab.5 Average through hole fill resistance changes during thermal shock -40°C ÷ +125°C, adhesive Elpox EXP 8.1, tube shape fill

N=80	Average through hole fill resistance R ± σ [mΩ]		
Diameter	0.30 mm	0.50 mm	0.80 mm
0 cycles	35 ± 7	23 ± 5	15 ± 3
200 cycles	34 ± 7	23 ± 5	15 ± 3
400 cycles	34 ± 6	24 ± 5	15 ± 3
600 cycles	34 ± 7	22 ± 6	15 ± 3
862 cycles	32 ± 8	23 ± 5	15 ± 3

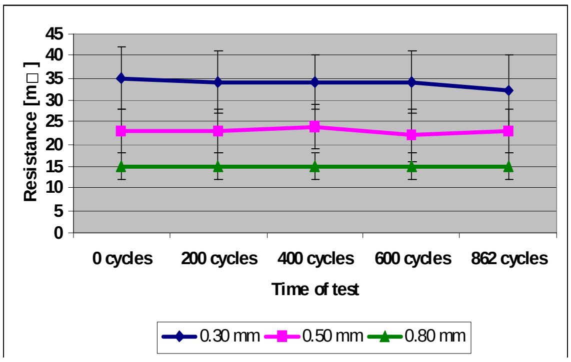

Fig.2 Tube shape fill resistance changes during thermal shock tests

The results of thermal shock tests for tube shape fills were shown in Tab. 5 and graphically presented in Fig.2. The fill resistance is slightly higher than for holes with full fill. It can be connected with adhesive thickness on hole wall. In tube shape hole the adhesive is present only on hole wall, with empty hole middle. For full fills adhesive is present in whole hole. In both cases the fill resistance changes do not exceed 10%. It is satisfactory results for practical applications.

5. CONCLUSIONS

The aim of the work was to investigate the resistance stability of through holes filled by electrically conductive adhesives. The new adhesives with the filler in form of mixture of Ag flakes micrometer size with Ag nanopowders were used in experiments. The influences of adhesive way of applying on fill resistance as well as fill resistance stability during climatic tests were investigated. Holes were filled by adhesive in two ways: by classical stencil printing and by printing with vacuum assistance. The fill resistances for holes diameter 0.3 mm are repeatable and lower than 25 mΩ. For holes diameter 0.5 mm and 0.8 mm the fill resistance below 20 mΩ and near 10 mΩ was obtained, respectively. Holes filled by classical way have lower fill resistance than holes filled with vacuum assistance. The fill resistance changes in both tests: storage (1000h & 125°C) and thermal cycling (-40°C - +125°C & 1000 cycles) are not bigger than 10%. Such results are satisfactory for practical application based on polymer materials.

6. ACKNOWLEDGMENTS

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