БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **71**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **71**

София • 2019 • Sofia

Optimization of thermal management of MCM

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Abstract: *The paper presents the results of the investigation of three chemical methods for via metallization of a multilayer multichip module's (MCM) substrate with a purpose - optimization of thermal management of MCM. Experiments and measurement results of heat transfer in multilayer structures of FR4 material with different topologies at the first and second levels are discussed. The purpose of the experiments is to provide metal (copper) deposition on the inner dielectric surface of MCM substrate vias and to create electrical connection between the layers. The thermal vias in the multilayer structures, connecting the top solder pads and the copper pads, are designed with a different diameter and a different width of the pads.*

Keywords: *heat transfer, metallization, multichip module's (MCM), vias*

1. Introduction

The trends to decrease geometry and merging more features into one electronic system have led to the development of new technologies for the assembly and wiring of integrated chips in a microsystem - a multichip module (MCM) [1], [2]. Typical for MCM is the common packaging of several chips on one chip-carrier to function as a single system. The common packaging greatly enhances the miniaturization and the functionality of these systems. Thermal vias connect the different layers in the multilayer structure. The technique relates to the deposition of copper film on the dielectric surface inside the drilled holes in the PCB material. The chemical methods for vias are used and have been successfully applied in the PCB industry for over 40 years. They differ in chemical composition, process sequence, chemical stability and feasibility. These methods consist of three major steps – dielectric surface activation, chemical electroless copper seed layer deposition and subsequent electrochemical thickening of the copper seed layer. The multichip modules are very usefull in the robotic industry. Thermal vias in the structure decrease the size of the integrated system, which is necessary for the small robots with many functions.

2. Chemical methods for via metallization

The first chemical solution, used for the investigation, is palladium activation system [3,4,5,6]. In order to be metalized, the dielectric surface is treated in such solution in several steps including Degreasing, Micro-etching, Oxide removing, Activation "Pre dip" bath, Activation bath, Post activator bath, followed by electroless copper deposition. The last step of the process will deposit a thin layer of copper.

The second dielectric activating solution is carbon-based [5]. The experiments were conducted with Activator 310. The activator comprises a water solution of carbon particles and organic binders with potential of hydrogen (pH).

The third, activating solution is composed of Copper hypophosphite, Ammonium hydroxide and wetting agent. The Copper hypophosphite has low thermal stability.

All the methods have the same purpose – to provide metal (copper) deposition on the dielectric surface inside the MCM vias and make connection between the separate layers. The vias will be needed for heat transfer in multilayer structure. Photo of the metallization vias is presented in figure 1

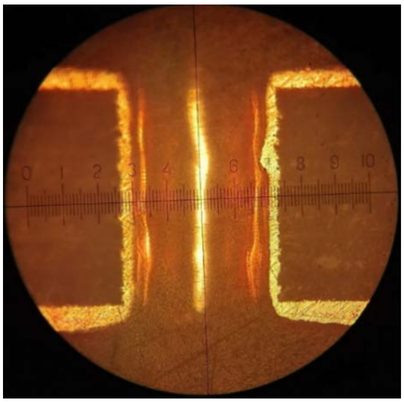
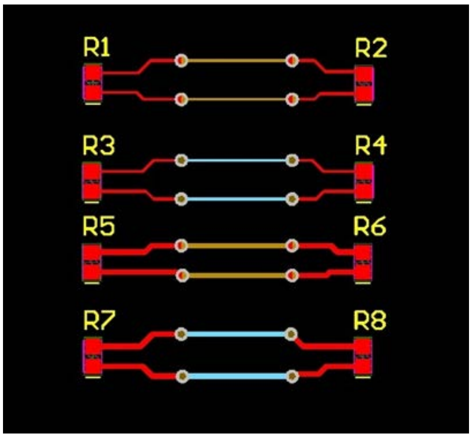


Fig. 1 Cross section of the metallization vias

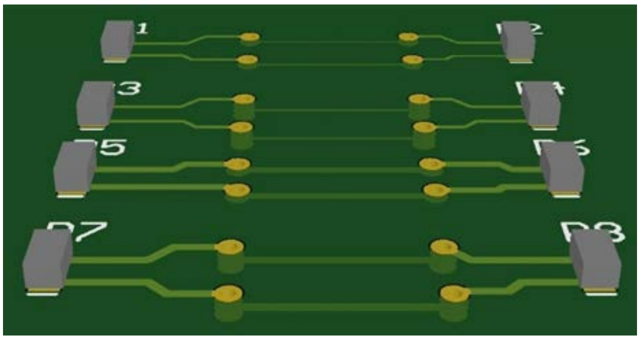
3. Experiments and results

In order to examine the dielectric activation capability of the three chemical methods cited above, test samples were prepared and their topology is shown in Figure 2. The size of the samples is 5x5 cm. The vias have different diameter and a different width of the pads.

The structure of fig. 2 contains 4 sets of conductor pads, starting at the top layer and passing through the internal layers of the MCM. For the purpose of the experiment various combinations have been designed such as varying thickness of the pads, the diameter of the vias, and width of the wires. By this topology, the heat transfer in multilayer structures of FR4 material was investigated. In fig 2 b) a three-dimensional view of the structure is presented.



a)



b)

Fig. 2. Test sample topology; a) project topology; b) three-dimensional view.

The technological order for the construction of structures includes the following steps:

1. cutting of the material;
2. drilling of the compatibility holes;
3. realization of the inner conductive layers;
4. lamination of the upper and lower conductive layers;
5. drilling of through holes - vias;
6. metallization the vias ;
7. formation of upper and lower conducting layers.

Thermal vias are tags punched in the source material to serve for subsequent alignment with photo templates as well as alignment between different conductor layers. The holes must be at least three in L-shape. In the presented case, four vias with a diameter of 1.5 mm, spaced 60 mm apart from one another, were used to realize the structures described above, beyond the functional part of the designed structures. The holes are drilled with the aid of LPKF's ProtoMat S103 PCB.

Photos of the prepared Test samples are presented in figure 3

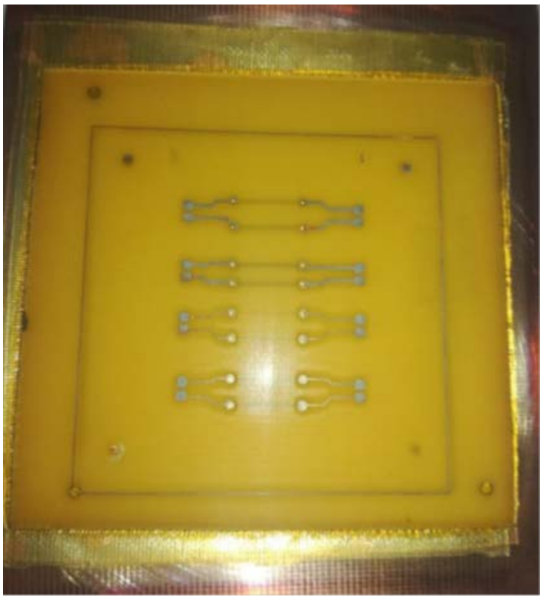
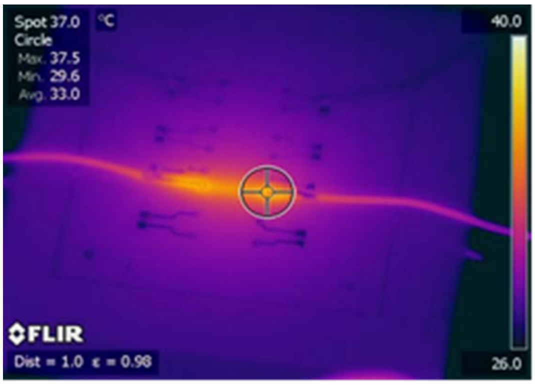


Fig. 3. Test sample.

The first two pairs of wires are designed with a thickness of 0.245 µm. The first pair of wires start from the top layer, passing through the second layer of the structure. The second pair run back from the top layer, passing through the third layer of the structure. The other two pairs of wires with a thickness of 0.470 µm, are similarly designed. The through holes are metallized using the above technology for 60 min and thus the thickness of the copper coating in the holes is approximately 25 µm. The thermal via diameter is 0,6 mm. The purpose is to investigate the change in the temperature at the different points in the structure when applying a different power supply. The measurement of the temperatures for obtaining the results is done by a thermal camera FLIR P640. A thermographic image of the experiment is shown in fig. 4



a)

b)

Fig. 4. Thermographic images; a) 0,245 µm width of the wires; b) 0,470 µm width of the wires.

Table 1 shows the values of the temperature at different currents across the structures.

Measurement point	Temperature of wire 0,470 µm (ºC)	Temperature of wire 245 µm (ºC)	Current (A)
Upper path	**31,3**	**34,2**	**2**
Lower path	**31**	**35,9**	
vias	**31,8**	**41,5**	
Upper path	**35,2**	**42**	**2,5**
Lower path	**34,6**	**43**	
vias	**35,6**	**50**	
Upper path	**41,1**	**51,2**	

Lower path	**40**	**52,6**	**3**
vias	**42,5**	**68,4**	
Upper path	**49,2**	**68,1**	**3,5**
Lower path	**47,7**	**68,8**	
vias	**51,7**	**92,3**	
Upper path	**58,1**	**84,6**	**4**
Lower path	**55,2**	**86,5**	
vias	**61,1**	**130**	
Upper path	**67,8**	**-**	**4,5**
Lower path	**64**	**-**	
vias	**71,8**	**-**	
Upper path	**79,7**	**-**	**5**
Lower path	**75**	**-**	
vias	**85,5**	**-**	
Upper path	**94,9**	**-**	**5,5**
Lower path	**86,9**	**-**	
vias	**102**	**-**	
Upper path	**119**	**-**	**6**
Lower path	**109**	**-**	
vias	**130**	**-**	
Upper path	**167**	**-**	**6,5**
Lower path	**134**	**-**	
vias	**176**	**-**	
Upper path	**187**	**-**	**7**
Lower path	**161**	**-**	
vias	**237**	**-**	

4. Conclusion

Measurements show that the 245 µm wide conductive wires heat up more than the 270 µm wide wires, resulting from the smaller cross section of the first. It has been proven that thinner wires can carry loads of up to 4 A without causing structure degradation. An intriguing fact is that almost the same temperature (at 4 amps on the thinner runways) is observed at the thicker ones at 5.5 amps, ie only 1.5 amps more than double. Therefore, tracks with a width of 470 microns can withstand 5.5 amps of load. Higher temperatures at the thermal vias are observed in all measurements. So it follows that thicker metallization and even filling the holes with metal or using larger diameter of the vias is necessary.

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Оптимизация теплового управления MCM

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***Аннотация**: В статье представлены результаты исследования трех химических методов сквозной металлизации подложки многослойного многокристального модуля (MCM) с целью оптимизации термического управления MCM. Обсуждаются эксперименты и результаты измерений теплообмена в многослойных структурах материала FR4 с различной топологией на первом и втором уровнях. Целью экспериментов является обеспечение осаждения металла (меди) на внутренней диэлектрической поверхности переходных отверстий подложки MCM и создание электрического соединения между слоями. Тепловые переходы в многослойных структурах, соединяющих верхние контактные площадки и медные контактные площадки, имеют разный диаметр и другую ширину контактных площадок.*

***Ключевые слова:** теплопередача, металлизация, мультичиповый модуль (MCM), переходы*