Nikola Stefanov Jordanov[1], Anna Stoynova Andonova,
Natasha Georgieva Atanasova

Technical University of Sofia, Dept. of Microelectronics, Sofia, 8, Kl. Ohridski blvd.

RELIABILITY IMPROVEMENT IN CONSEQUENCE OF INVESTIGATION PCB SILVER ELECTRCHEMICAL MIGRATIONS

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Looking for a compromise between high functionality and convenient and effective materials the silver has got many proved and achievements qualities for PCB. The main problem in using as a constructive materials its high disposition of migration. The investigation of a concrete type of migration between silver conductors is the goal of the paper. For this purpose an investigation techniques is presented to qualifying PCB structures. Some test structures are designed and produced and experimental results are results are analyzed.

1. INTRODUCTION

The silver because of series of his advantages is one of basic metals that are used for conductive systems in the microelectronics. It is well – known that the silver is first metal for that the electrochemical migration was observed. The micro miniaturization in the microelectronics reaches to a level where the physical and the chemical properties of the solid depend on his geometric size. However the structure of constructive elements is essentially heterogeneous in consequence of the non-uniformity of physico-chemical processes when it is formed. Namely the structure predetermines the degradation and failures of the devices when operate. With increase the integration’s degree in the PCB systems, the electro migration in the thin-film and thick-film conductors was confirmed as one of the basic reason for the failures.

The electromigration of the metals is expressed in accumulation of mass of the metal on the conductive layers. In result of that a conductive mass is built up on the one of conductors and the other one become “becomes poor” of mass, consequently voids are formed, later they grow in leaks and breaks in conductors. On principle the direction in which the ions are moved in conductors depend on the structure of pattern and the type of the carrier of the charge. The silver’ s ions migrate from anode to cathode.

In this paper the electrochemical migration of silver with the help of test structures that are constructed for this objective is investigated. A new approach for analysis of data from the electrochemical migration for qualification of the PCB structures is proposed.

2. ELECTROCHEMICAL MIGRATION

During the electrochemical migration process, the metal that disposed on insulator is migrated by ionic conductivity across the electrolyte's thin –film on the insulator and is precipitated on the metal of the neighbor conductor. This process includes three stages:

- Electro-dissolution of the anode (more often than of cathode)
- Ionic carrying by electromigration
- Electro-deposition

For appearance of electrochemical migration are necessary the following conditions:

- Between the migratory surface in the migratory field must have sufficiency of liquid electrolyte
- The applied voltage must be higher than the sum of anode and cathode potential
- The current density must be high close to the peak of the migratory formation (dendrite)

If one of these conditions is not realized, the electrochemical migration doesn't execute. For this type of the layers migration there are influence factors as:

- Kind and composition of the layers
- Geometry of this layers
- Type of carrier
- Thickness of the layers and distance between them
- Temperature.

3. INVESTIGATION TECHNIQUE OF THE ELECTOCHEMICAL MIGRATION

Two groups of methods are existed for investigation of the electrochemical migration.

3.1. Temperature – voltage – humidity method (TVHM)

TVHM is realized with investigated conductors are placed in humid environment under defined temperature and applied voltage in camera for accelerated tests. It is possible varying of these conditions of the test and using of different gas pollutions (SO_2, H_2S, HCl) i.e. exist controlled environment. The mean time of failure during the test varies from several weeks to months.

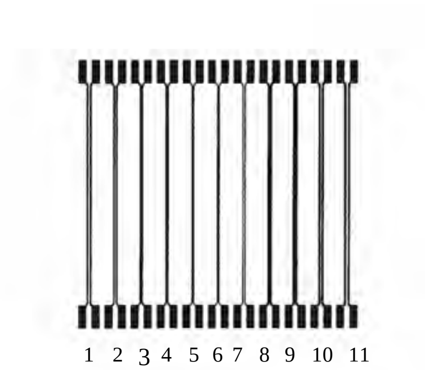
In this paper is presented results from another test – "drop test", because TVHM method is more specific and slower.

3.2. Method – "Drop test"

This method is realized as between two neighboring thin-film conductors, lying parallel is applied voltage and is placed drop-distilled water. All conditions can vary. Instead water, can be used solutions of electrolytes that contain NaCl, KJ, citric acid, sodium carbonate and. The velocity of electrochemical migration for drop test is 10^4 times higher than velocity of the TVH test because of this that test is accepted as accelerated test for an investigation of the process.

4. METHODS OF INVESTIGATION

With the purposes of investigation are designed and manufactured structures shown of Figure 1.



a)

Number of line	Width of lines	Distance between lines
1	300	300
2	300	225
3	300	100
4	300	50
5	200	150
6	200	100
7	200	20
8	400	50
9	400	100
10	400	200
11	400	300

b)

Fig. 1. Testable structures for investigation of electrochemical migration
a) Photo of testable structure
b) Size of the elements of the structure

The testable structures give possibility to investigate electrochemical migration when vary following parameters:

- Width of the metal conductive lines
- Distance between metal lines
- Depth of metal lines
- Different type of carriers
- Availability or absence of insulator between metal lines
- Technologic of metal formation

"Drop test" was carried out with drop 0.01ml of destilled water or 1 % weight solution of citric acid or1 % weight solution of sodium carbonate.

In order to form thin-film metal system was optimized the composition and the conditions of precipitation of alloyed silver layers which consist (0.5 – 2.5 %) antimony. To expand the range or basic technological parameters and obtaining layers with bettered physico-chemical parameters some investigations are made for specifying possibility of different:

- compositions of the electrolytes and
- Mode of precipitation of allowed silver layer (dc mode, impulse mode and impulse mode with reverse).

Each mode is characterized with two basic parameters as shown in Table 1.

Table 1

Different mode parameters of allowed silver layer's precipitation

MODE	PARAMETERS	
DC	Cathode current density, Dk	Time duration, t
Impulse mode	Amplitude current density, Dka	Duty cycle, ✈
Impulse mode with reverse	Cathode amplitude current density; anode amplitude current density	Duration of cathode or anode impulse

Three type carriers were used into experiments:

- Sital undercontact metallization from NiCr, NiAu
- PCB material with undercontact cooper foil (depth 10μm)
- Alumooxideceramic with undercontact metallization from NiCr

It was measured RF parameters of migratory process with signal generator SMS2, vector analyser ZPV and adapter ZPV-25. It was concluded that as amplitude-frequency response (AFR) reached 0dbm, as process of electrochemical migration is advanced. Circle diagram (Smith's diagram) is also an indicator of migratory process level.

In Figures 2 a, b, c it can be seen effect of current flowing via drop from the anode to the cathode during that Ag bridges is created from anode to cathode also. High and relatively constant value of migratory current during the third stage of curve is due to electron conductance via Ag bridges connect the parallel wires.

Notes: 1 – conductor with Ag layer connected to cathode
2 – sital's surface between conductors
3 – conductor with Ag layer connected to anode
4 – Ag bridges over insulator

Width of conductors is 400μm, and distance between them in the pictures is 200μm.

Stability of thin metal layers against destruction as a result of electromigration depends on different factors-conditions of creating and exploitation. Because of that one of basic tasks is creating of effective methods for protection of electromigration.

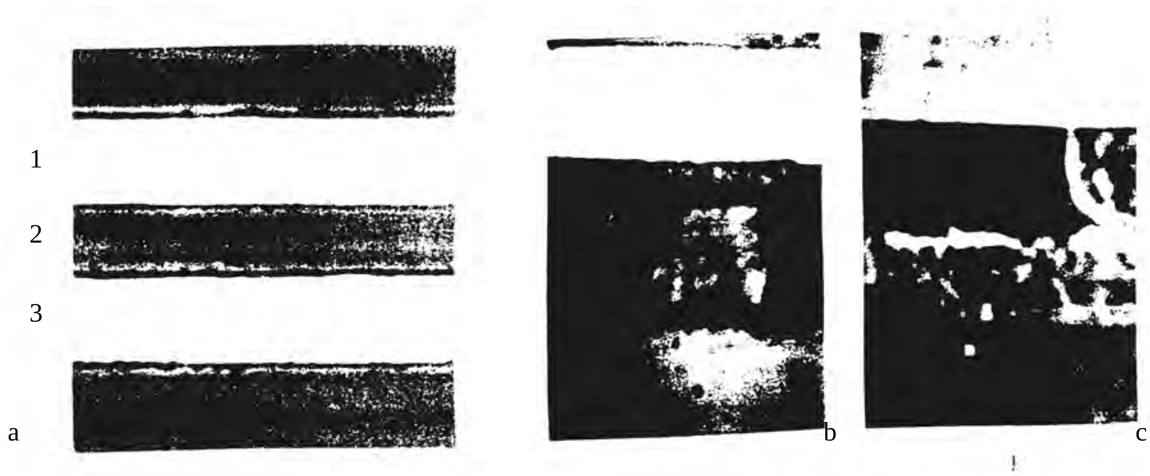


Fig. 2. a) appearance of wires with electrochemical AgSn layer before electrochemical migration b) appearance of wires during migratory process c) appearance of wires after migratory process during fault current

5. EXPERIMENTAL RESULTS

Experimental results in that paper was given in migratory curves - migratory current depending on time. Each migratory curve is consisted from three stages, that correspond to stages from the process:

- *Stage 1*- simultaneous electrochemical dissolvance and passivation of anode under electrical field. In this stage "the drop"is saturated with Ag ions.
- *Stage 2*- transference of Ag ions from anode to cathode by electromigration and precipitation of Ag over insulator.
- *Stage 3*- metal reducing and precipitation over insulator and cathode. In this stage the metal system is short connected and failed.

Results analyze includes:

- influence of type of Ag layer over electrochemical migration
- influence of carrier over electrochemical migration
- influence of distance between conductors over velocity of electrochemical migration (Figures 3, 4, 5, 6).

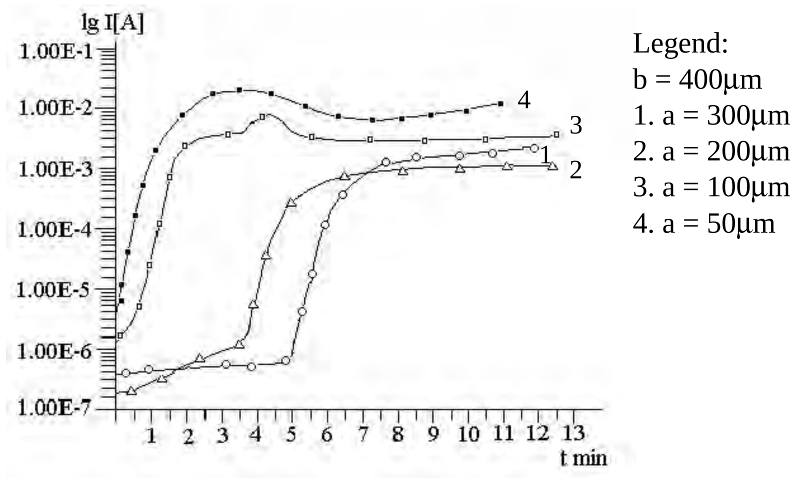


Figure 3. Migration current vs time duration of poor Ag layer deposited

In Figures.3 and 4 are given migratory curves of Ag and AgSn layers. Width of the electrochemically formed layers is 6µm, and the analyzing carrier is sital.

From Figure 3 it can be seen that conduc- tors formed from Ag have the bigger inclination to electromigration referenced to AgSn (3.81 %). This is most obvious when distance between conductors is from 200µm to 300µm.

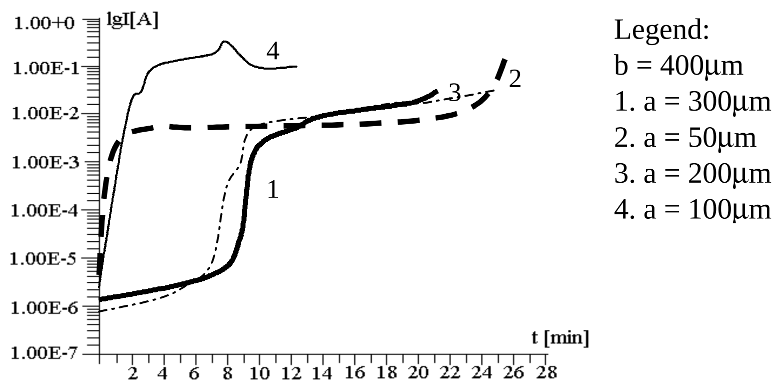


Figure 4. Migratory current vs time duration of Ag-Sn layer deposited

The Ag layers have the faster migration (25 %) in the first and in the second stage of migratory process. When the distance between conductors is from 100µm to 150µm, process rate for conductors becomes commensurable. It is important to say that when the distance between conductors is small it can't been detected the first stage of the process. Obviously in this case the saturation's time duration of drop destilled water is too small and begin the second stage of process-transfer of Ag ions from anode to cathode.

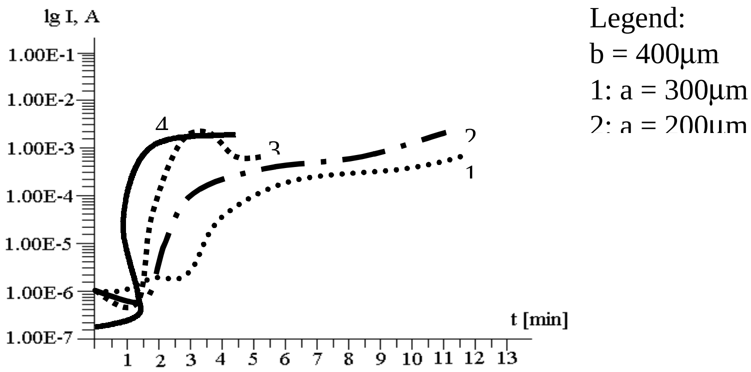


Figure 5. Migration current vs time duration
of Ag-Sn layer deposited on PCB material

The third stage of migratory curves in Figures 3 and 4 noted like "failure stage" is characterized with defined values of migratory current. For Ag conductors the fault current has the smaller values that is the reason for faster electrochemi- cal migration.

The influence over the electrochemical migration of the distance between conductors was considered over three carriers: sital (Figure 3 and 4), PCB material (Figure 5) and alumooxide ceramic (Figure 6).

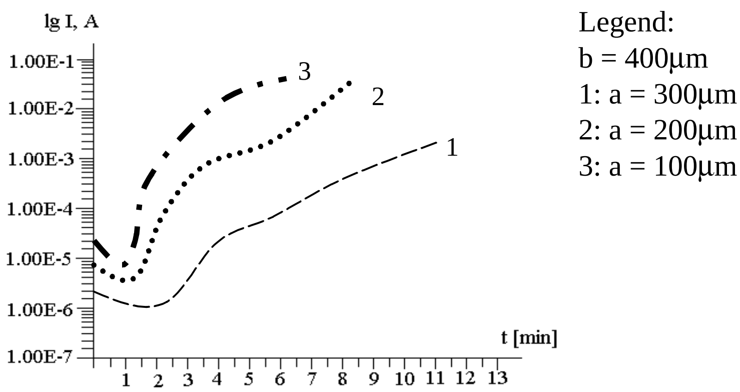


Figure 6. Migration current vs time duration
of Ag-Sn layer plating on Ag_2O_3 ceramic

The fault current in the all figures increases during the migratory process as a result of faster flowing of ionic current from anode to cathode. The electrochemical migration of Ag-Sn conductors over sital is slowest when the distance is greater (Figure 4). For Ag conductors the rate of elec- trochemical pro- cess increase, but is from the same order (Figure 3).

When the substrate is PCB material the pro- cess rate increase two times (Figure 5), over alumo- oxide carrier the increasing is 2.5 times. This is when the distance between conductors is big - 300 and 200µm. When the distance is 100 and 50µm the process rate decreases. Over sital the process rate is too high for the two type conductors, over PCB material the process rate decreased twice, over alumooxide ceramics decreased once. Synonymous explanation can’t be done in this case. In this case influenced the following factors: type of undercontact metalization, type of substrate, their construction, passivation of the anode etc.

6. CONCLUSIONS

The electrochemical migration rate of pure Ag conductors is higher than that of AgSn conductors (3.81 %). When the distance decreased, independent of the other conditions-the migratory process rate increase. The substrate influence over the electrochemical migration rate also. When the substrate is sital the process is slower, but when the distance is bigger. At the other two cases the rate increase.when the distance is 100 and 50µm the results is opposite.

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