PRODUCTION OF 3D CONTACT STRUCTURES USING THE LIGA METHOD

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The purpose of this report is finding an alternative method for 3D contact structures production, which is different from traditional silicon technology. The LIGA method showed capability of preparing such structures. For that purpose the technological sequence for LIGA process implementation in making of functional contact is investigated and improved. In order to make the contact commutate the circuit without human taking part in the process the bimetal effect is used. The test cantilever beams are made of two materials with different coefficients of linear expansion. For that reason when temperature rises the beam leans towards the material with lower coefficient and that makes commutation possible. In this paper the technological sequence for preparing such bimetal structures and results from experiments for checking their functionality are given.

Keywords: 3D contact structures, LIGA method, bimetal effect

1. INTRODUCTION

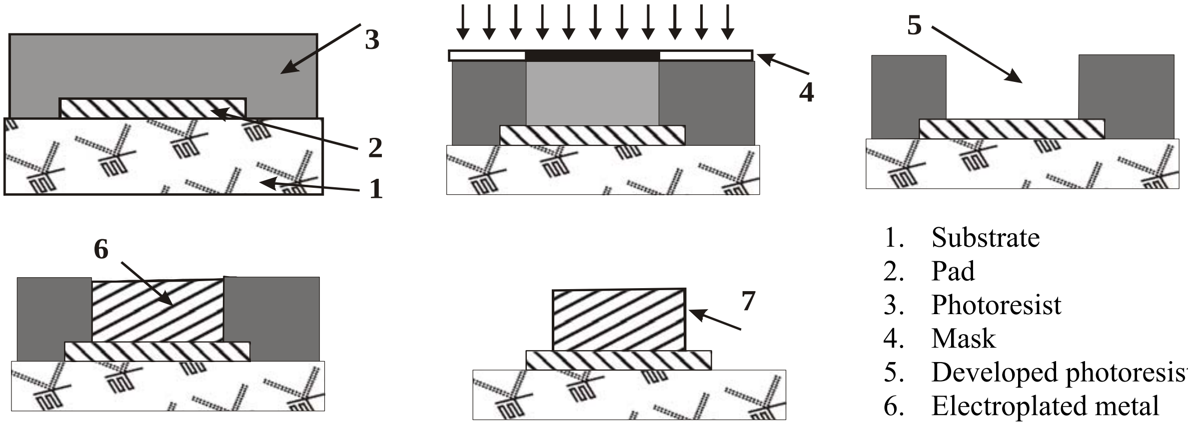
In the contemporary electronic devices different microcontact and micromechanical structures are increasingly used. As a classical method for production of 3D structures the standard silicon technology is used [1]. The different types of microcontacts can also be considered as a 3D structure [2]. They can have various constructions and applications. Some of these contacts are elements of sensors and actuators [3]. A number of micromechanical elements are being produced using the LIGA method [4].

The purpose of this report is to be developed technological process for implementation of a functional microcontact device using the LIGA method.

The principle of LIGA method is creating a 3D image in photoresist followed by filling the opened structures with electroplated metal. The technological sequence is shown on figure 1.

Depending on the process, different kinds of photoresists resistant to the specific electrolytes are used. Negative photoresistive films are more frequently used due to their higher resistance.

Usually, for classical LIGA process aspect ratios greater than 5 are accomplished but other aspect ratios are also possible to maintain. Depending on the depth of the desired structure a different type of photoresist is used. The greatest aspect ratios when thick photoresist is used are achieved by implementing X-ray lithography. When thickness of dozens of microns is required the UV lithography is also applicable. Using of both projection and contact photolithography is possible.



1. Substrate
2. Pad
3. Photoresist
4. Mask
5. Developed photoresist
6. Electroplated metal
7. Photoresist removal

Fig.1. Technological sequence for LIGA process

While accomplishing electroplating the crystalline structure of electroplated metal, the internal stress and the plating speed are of great importance. Depending on the size and process conditions different side effects may be observed [5] .

2. CONSTRUCTING OF A FUNCTIONAL CONTACT.

Every kind of contact realizes certain function but the purpose here is to utilize different effects to make the contact commutate the circuit without human taking part in the process. These effects can be mechanical, magnetic or thermal. Examples of some contacts used in thermal sensors are shown on figure 2.

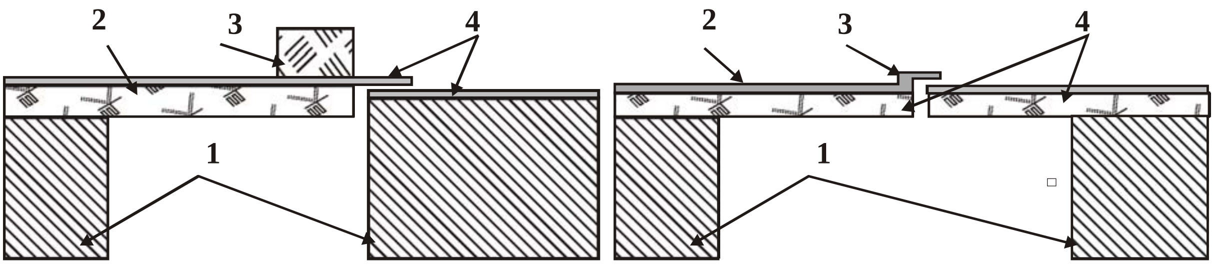


Fig. 2a Fig.2b

A structure with cantilever beam 2 constructed on the substrate 1 from conductive material 4 is shown on figure 2a. At the loose end of the cantilever beam an element 3 with certain mass is put on. When mechanical force is applied in vertical direction the two layers 4 will come into contact. Likewise on figure 2b if the two layers are from magnetic material when magnetic field is applied to the structure a contact in the area of element 3 will be realized.

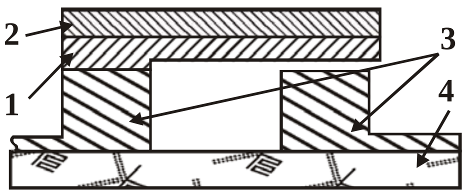


Fig. 3

When there is e certain need for accomplishing electrical contact under thermal influence a bimetal structure may be used. For that purpose the cantilever beam is made from two materials with different coefficient of linear expansion. In that case the cantilever beam will deform under thermal influence. Construction of that kind of contact is shown on figure 3.

The cantilever beam is made from metals with different coefficients of linear expansion. For example the layer 1 may be Fe, Ni, Fe/Ni and layer 2 – Cu. The contact is realized between leads 3. In absence of thermal influence there is space between the loose end of cantilever beam and the lead. The structure is made on dielectric substrate 4. When heat up the Cu-layer expands more than the other layer and the cantilever beam bends downwards.

3. TECHNOLOGY.

The technology for making the upper structure is entirely based on LIGA process. It consists of consecutive realizing of the different constructive elements. In order to define the process conditions a test structure with more than 150 different modifications is made. These modifications are constructed as groups on test electrical tracks. The topology of test tracks is shown on figure 4 and it is done using the standard technology for producing printed-circuit boards. The small round pads are used for building the studs for the cantilever beam and the big ones for realization of the test measurements. All of the elements are connected to one another with electrical tracks in order to achieve electrical connection for the electroplating process.

The photomask for realizing the studs is a system of circles with different sizes in order to experiment on different combinations of contacting areas. The centers of the studs coincide with the centers of the contact pads of the tracks.

In order to obtain a gap between the contact stud and the bimetal cantilever beam a photoresist layer is used. The photomask used for creating the photoresist image is shown on figure 5.

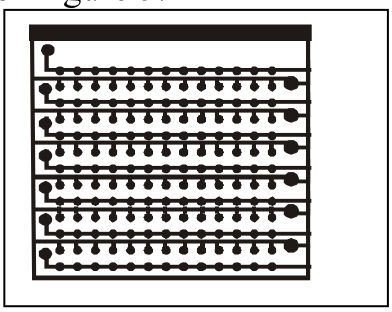


Fig.4

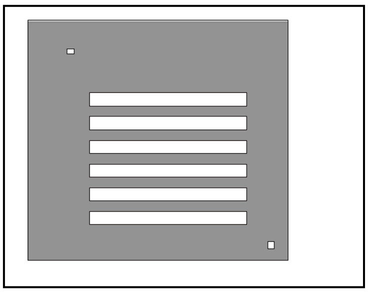
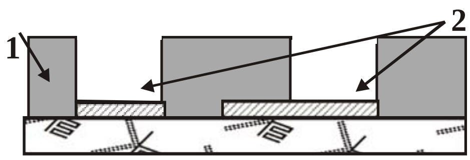


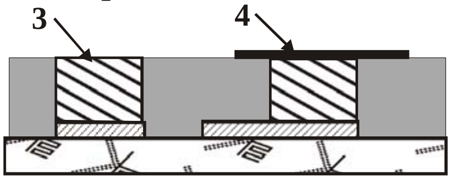
Fig.5

The cantilever beams are with the same length but different width. All the structures have the same thickness as they are produced in an integrated planar technological process. The technological sequence for making the structure mentioned above is shown bellow.

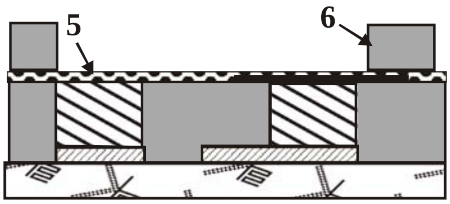
Standard technology for printed-circuit boards producing.



Laminating the substrate using thick negative photoresist and photolithography to open the structures where the studs will be electroplated.



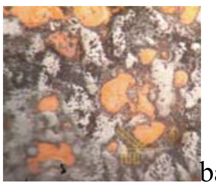
Electroplating of studs of copper 3 to the photoresist level. Photolithography doing of liquid photoresist in order to form the insulating layer 4. This process is obtainable because of the insolubility of the dry into the liquid (LSI) photoresist and its developing solvents.



Activating the surface in order to achieve conducting characteristics 5 and photolithography of the thick negative dry photoresist 6 for opening the structures where the bimetal cantilever beam will be electroplated. In making of activation layer a certain procedure is used to achieve better adhesion of the electroplated layers [6]. The purpose is to remove the activator on the stud because of its low adhesion to copper. The next step is permalloy electroplating followed by copper electroplating to construct the cantilever beam. After electrodeposition the photoresists are removed. There are several procedures for removing the dry photoresist, liquid photoresist and the remains of the activator.

4. EXPERIMENTAL RESULTS.

A couple of issues were investigated during the experiments. The first one concerns the creating of bimetal structure by electroplating permalloy on copper finishing. For the purpose for different current densities permalloy is electroplated on copper foil. Cases of non - optimized and optimized process is shown on figure 6.


bad structure

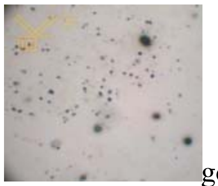
good structure

good structure

Fig. 6

The following experiments concern the processes of creating the cantilever beam, electroplating studs and formation of the beam. For the purpose the test photomasks from [6] were used. The difference here is that bimetal cantilever beam is constructed.

The electroplated beam structure after photoresist removal, longitudinal and cross-section and permalloy-copper bimetal structure are shown on figure 7.

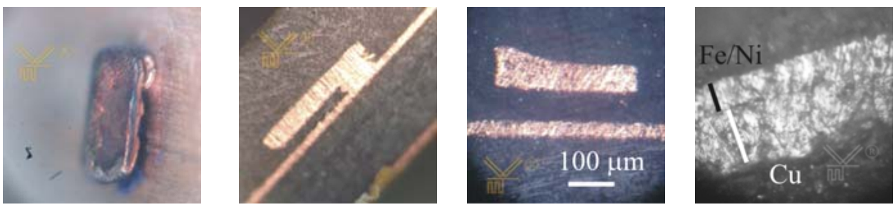


Fig.7

Over 400 structures were made and the difference here is that the upper layer was from permalloy, not like in the main case where it is the first layer. In the main construction some more complex 3D elements were used. In order to produce a real functional 3D structure to react to temperature variations a cantilever beam is included in the photomasks with one end on two studs and the executive contact on one stud.

A stage of the production of experimental structures is shown on fig. On single substrate four blocks of test structures are made. On the left side of each block the 3D cantilever beams can be seen. Part of the process of photoresists removal is shown on figure 8

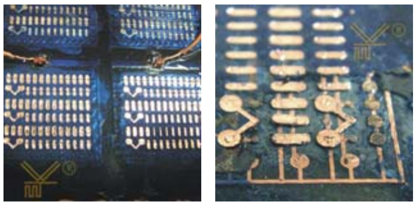


Fig.8

In order to define the conditions for contacting and deformation cantilever beams with different sizes are constructed (figure 9)

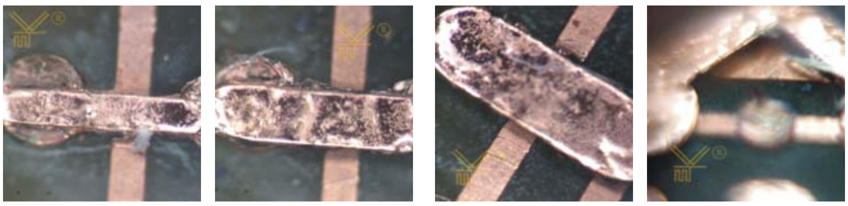


Fig.9

Fig.10

For creating the gap between the loose end of the cantilever beam and the stud a liquid negative photoresist with different thickness was used. The thin layer is spin-coated and the thick one is applied by dipping. A cantilever beam cross-section when thick negative resist is used is shown on figure 10, where 1 is supporting stud, 2 is the beam and 3 is the contacting stud.

5. CONCLUSION.

During functional testing the following facts were noted:

- The testing of bimetal elements showed that they function. But at this point their sensitivity is very small – 10 degrees leaning for temperature variations over 150^{o}C.
- When electroplating permalloy in deep cavities (the second structure) there is a big difference in process conditions compared to electroplating on macro samples.

- Further testing is needed in order to decrease the electroplated structure unevenness.
- The using of thin negative photoresisit has to be improved because almost every sample showed short circuit.
- The yield is very low – under 1 per cent (from over 700 structures only 4 worked)

The realized technological sequence showed availability for creating 3D functional contact structure but in order to maintain high productivity it is necessary to run some more tests in the following fields:

- Optimization of the electroplating conditions in small apertures has to be made with adhesion and internal stress taken under consideration.
- Determination of the optimal thickness ratio between the two layers.
- Determination of the fatigue conditions in the structure.
- Determination of the contact resistance and heating in contact area.

6. REFERENCES

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