ELECTROCHEMICAL FORMATION OF THREE-DIMENSIONAL GOLDEN MICROCONTACTS

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Electroplating of golden layers is often used in the microelectronic devices. This paper reports our experimental results from formation of golden micro - contact elements – bumps with diameter 300µm, developed by UV-LIGA process. The gold-acid-cyanide electrolyte, which is used, has no influence on the dry negative photo-resist (PR). We investigate different electroplating regimes – direct current and impulse-current regimes, the uniformity of micro - contact elements (MCE) growth over the matrix surface and the kind of bumps' surface.

Keywords: electroplating, bumps, flip-chip, gold

1. INTRODUCTION

At present time the surface assembly technique is developed to such a rate, that every mounting method, which gives endmost results, can be accepted as suitable. It refers in a high degree to the implementation of the technological method UV-LIGA. MCE can be formed electrochemically of many metals and alloys. The MCE made of gold are very typical in the development of semiconductor devices, modules and systems.

There are many articles about elaboration of MCE made of gold and copper.

In their paper Blaga and co-authors [1] give the results of electroplating development of cupric bumps with diameter 150µm.

The possibilities of UV-LIGA method for development of MCE made form copper for flip-chip assembly, without any temperature processes are heard in different articles [3,4,5,6,7,8].

MCE – bumps made of gold using a sulfite-based electrolyte are noted in another article [2].

2. PROBLEM STATEMENT

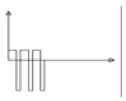
For the purpose of our investigations is used gold-acid-cyanide electrolyte, which contains gold as metal – 10gr/l (in $KAu(CN)_2$ form), phosphate and citric buffer. This electrolyte works at pH=4.2 and has shown its suitability in conjunction with 35µm thick dry negative photo-resist Riston 215.

There are investigated different current regimes:

- direct-current regime (DC) 
- impulse-current regime with Θ=10% (IC) 

- impulse-current regime with constant duration cathode component with low- value current (IC-1)

- impulse-current regime with high-value current anode component (IC-2)



There are two main parts of the investigations:

- optimization of the electrolyte working regimes by a current-range measurement, which gives qualitative gold layers; speed of plate's precipitation and the cathode current density usage. The choice of the most suitable regime is taken on the base of compromise between the best values of the three electrolyte's parameters.

- development of MCE – bumps with diameter 300µm, situated in a matrix of 36 numbers, at a distance of 2 mm between each other. For PCB plate is used patterned organic dielectric Rogers 4003 with 18 µm thick copper foil.

Microscope was used to evaluate the smoothness of the Au-deposits, the heights of the MCE on the selected rows of elements and the heights in different parts of the surface. Fig.&& shows a microscopy photographs of Au-bumps.

Fig.1 shows the position of the measured MCE's.

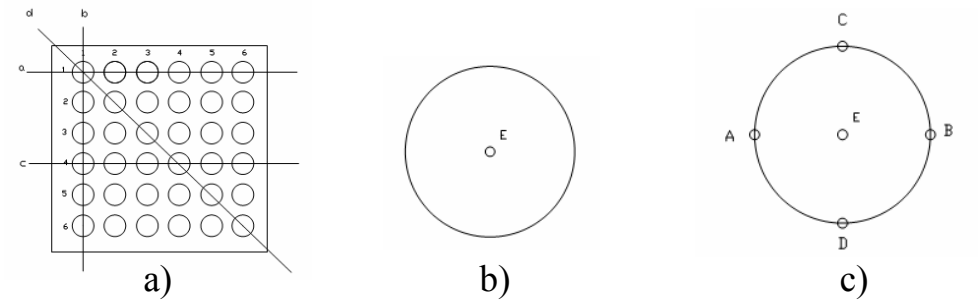


Figure 1. Schematic of the test-structure matrix with the position of heights' measurements – a), places of MCE's heights measurements –b), c)

3. RESULTS

3.1. Optimization of the electrolyte's regimes for gold electroplating

Fig.2 shows the cathode-current range at the three working temperatures.

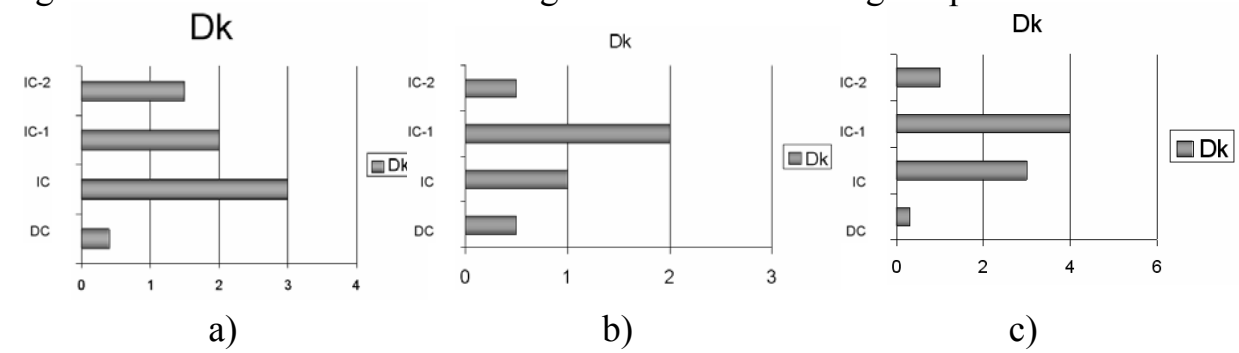


Figure 2. Range of working-cathode current for gold electroplating at the four current regime and three different temperatures – a) 20°C, b) 40°C, c) 60°C.

Fig.2 shows also that at the direct-current regime (DC), when heated from 20°C to 40°C and 60°C, it has no essential influence on the investigated parameters. The

usage of the impulse current enlarges the current values from 2 to 6 times for the different regimes, as the higher temperature gives advantage to the IC-1.

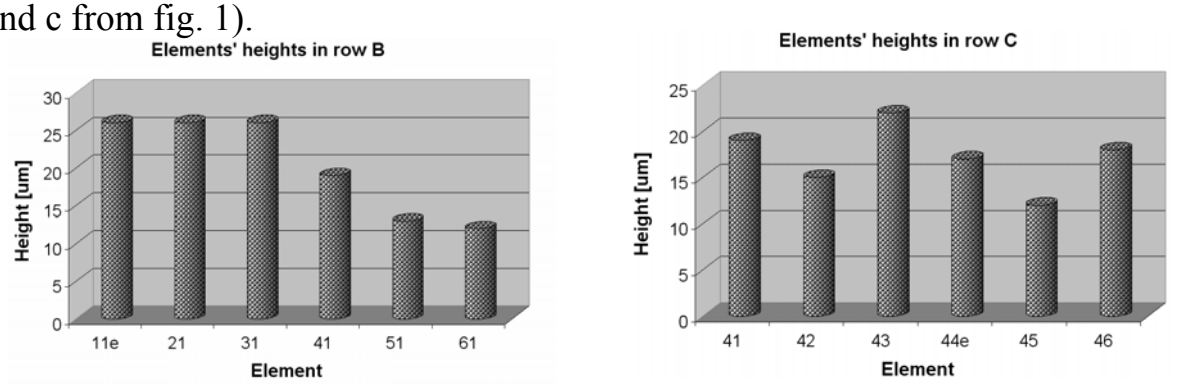
The electrolyte's plating speed in all investigations varies from 0.01 to 0.5µm/min, in the most cases it is between 0.1 and 0.3µm/min, which is satisfactory for gold electroplating electrolytes. With the increase of the cathode current – the plating speed also raises. In the cases of working with impulse current, the plating speed decreases, which is clearly expressed in both cases – IC-1 and IC-2. There is also observed higher speed when the electrolyte is heated.

The cathode-current density usage of the electrolyte decreases with the raising of its working temperature. The cathode-current usage decreases when the current regimes are IC-1 and IC-2. The values of this parameter vary between 10 and 68%.

Based on the conducted investigations for development of golden MCE, DC and IC with cathode-current value of 0.3 and 3A/dm^2 and working temperatures at 20°C and 40°C were chosen.

3.2 Electrochemical development of golden MCE-bumps from. Elements' parameters.

The uniformity of MCE growth on the matrix surface, when implementing direct current regime and electrolyte working temperature at 20°C, is shown on fig. 3 (rows b and c from fig. 1).



a) b)

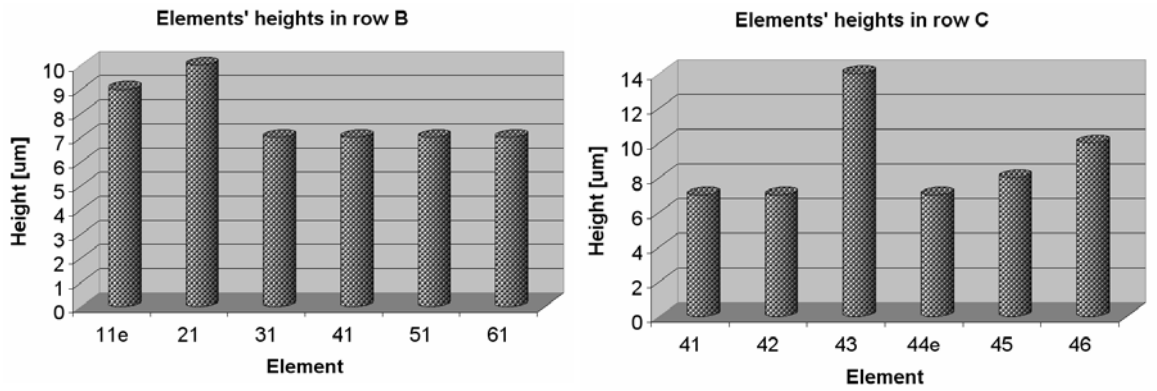
Figure 3. Heights of MCE in [µm] for rows b – vertical – a) and c – horizontal – b) as it's shown in the fig. 1 a), the current regime is DC, the temperature is 20°C.

Figure 3 shows that the horizontal row (c) is characterized by its irregularity in the MCE's heights. The reasons for that are the low dispersion capability of the golden electrolyte and the unsatisfactory stirring of the electrolyte bath. In the vertical matrix's row (fig. 1 - b) from the top to downwards, at the level of sample plunging into the electrolyte, the MCE's heights decrease uniformly, which is typical feature for the PCB technology, despite of the small dimensions in the investigated structures.

On figure 4 are given the elements' heights for the same MCE's rows, which are formed at working temperature 20°C and current regime – IC.

Figure 4 shows that in this case the MCE's development is at lower speed. In both rows of measuring, the growth in height is more uniformly. This issue proves that the usage of impulse current brings to a tendency of alignment in the MCE's heights.

That can be pointed out as the main advantage in impulse current implementation. In this case the speeds of growth are also higher – 0.19 and 0.22μm/min.



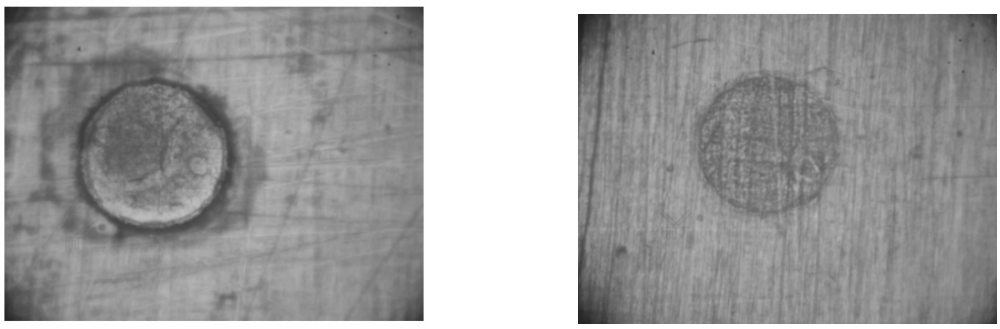
a) b)

Figure 4. Heights of MCE in [μm] for rows b - horizontal and c – vertical as it's shown in the figure 1 a), the current regime is IC, the temperature is 20°C.

The same investigations were conducted for working temperatures at 40°C and 60°C also. The measured MCE's heights show that when the temperature goes up, the irregularity of the elements' growth also increases.

Investigations for the type of MCE's surface were also performed. The measurements of the MCE's heights, which are depicted on the schematic, given on figure 1-c, show that in the middle of the elements is placed their highest point, and the height decreases from the middle to the edge of the MCE. The measurements at the edge of the elements don't give any dependency on the current regime and electrolyte working temperature.

The microscopy photographs on figure 5 illustrate the type of the MCE's surfaces.



a) b)

Figure 5. Microscopy photographs made on the MCE's surface, developed in two regimes: a) direct current regime and b) impulse current regime.

The pictures also show the smoother surface of the elements, developed by impulse current implementation.

4. CONCLUSIONS

The conducted investigations reveal the following issues:

4.1. The chosen composition of gold electrolyte is compatible with dry negative photo-resist, preliminary stabilized for 20 minutes at temperature 120°C. The electrolyte works in a wide range of current values and has good plating speeds. The used impulse regimes enlarge the ranges of working cathode current values, but also decrease the speed of electrolyte's electroplating.

4.2. The measurements of the MCE's heights on the matrix's surface, shows that the direct current regimes give irregular growth. There is no doubtful fact in the tendency of alignment in MCE height, when is used impulse current regime – IC.

4.3. The MCE's surface can be considered for tabular with rounded edges. In the case when working with direct current regimes, the MCE's surface is irregular. There are micro grooves and bulges on the surface on different places. The implementation of impulse current regime – IC gives smoother surface, which is also confirmed by the microscopy photographs.

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