Galvanotechnical Manufacture of Parts of Electrical Components using Pulse-reversed current

Zoran Stević, Mirjana Rajčić-Vujasinović, and Dragan Topisirović

Abstract- Electrochemical deposition of gold, silver and similar precious and non-ferrous metals is of great importance for quality manufacture of fine electrical components, for example of integrated circuit pins. This paper presents procedure of modeling of such galvanic plating processes. Successful modeling enables automation of layer forming process and its control using PC-based system and appropriate software. Also, the advantage of pulse-reversed regime which is related to forming a uniform thickness of layer, radiance, adhesion and substrate sharp edges tracking is shown.

Keywords - Pulse current, Pulse-reverse current, Plating, Au, Ag, Cu, ORCAD, Simulation, Plating bath

I. Introduction

Galvanic plating of electrical components often uses cyanide electrolytes because they provide the best current distribution on the surface of an object on which the layer is deposited to, and so in that way its uniform thickness [1], [2], [3]. From the quality aspect of working and living environment those electrolytes are, however, very harmful. It is proved that there is a possibility that quality layers on complex form objects are obtained also from non-complex electrolytes if pulse and reverse currents are applied. Pulse and reverse current regimes are used for obtaining layers with better characteristics in aspects of radiance, adhesion, edges tracking and uniform deposit distribution on complex form objects, in opposite to layers which are obtained using constant current [4], [5], [6]. Those are the reasons why in contemporary industrial plants, especially galvanic ones, very often current sources with fast and simple changes of current direction and intensity are needed, or even with a desirable current shape in time.

The development of electrical and computer equipment opened the possibilities of obtaining an arbitrary intensity or current shape in time, with complete process automatization and introduction of necessary feedbacks for system breakdowns elimination.

Here, the application of one such system is described – bipolar current source with a possibility of assigning time intervals and current intensities in one or in the other direction, for electrochemical deposition of silver and gold on electronic components of small dimensions. Silver is applied as a layer on electrical contacts and conductors, especially in high-frequency electronics, or as a protection from corrosion of devices in chemical industry because of its high electrical conducting characteristics, mirror radiance and chemical stability both in alkali as well as in solutions of majority of organic acids.

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II. Experimental section

A. Experimental technique

The experiments are performed using a pulse-reverse current source up to 50 A, so in pulse period so in a reverse period, as showed in Figure 1. Complete system is based on Pentium IV personal computer and LabVIEW software platform [7], [8]. Interface, current amplifier and application software are the result of authors' own development [9], [11]. Device for generating of pulse-reversed current, which is completely computerized, tracks galvanic cell response by registering changes of cell voltage in time during the whole process and records them on assigned address under a name which is defined by user. Then, data can be processed and showed in an arbitrary way.

Fig.1. Computer controlled pulse-reversed current source

B. Experimental results

Preliminary experiments of galvanic deposition of silver and gold are performed with pulse and pulse-reversed current [11], [13]. These experiments showed that the best results are achieved when using pulse current when radiance of obtained layer is set as a criterion. Further experiments have confirmed that longer pauses also provide better results, so the regime of pulse and pause ratio 5s : 1s is adopted as optimal.

Diagram on Figure 2 shows first 10 periods of galvanization cell voltage response, which correspond to the experiment with current density of 100 A/m^2 with a duration of pulse 5s and pause 1s. The plate thickness of 10 µm is obtained by such regime in a classic electrolytic cell. This layer cross section look is showed in Figure 3. It can be seen that the layer is of very uniform thickness and very compact.

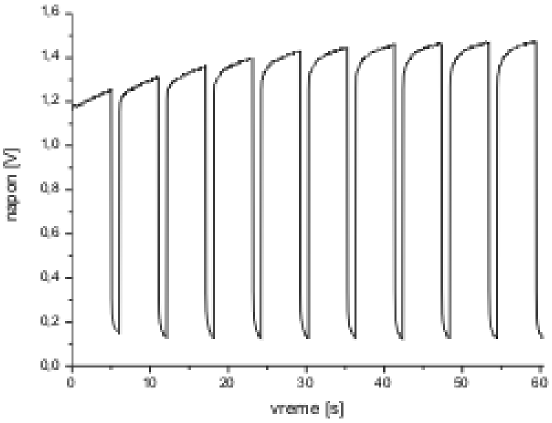


Fig.2. Cell response during deposition of silver by current of density 100 A/m^2 with pulse duration 5s and pause 1s

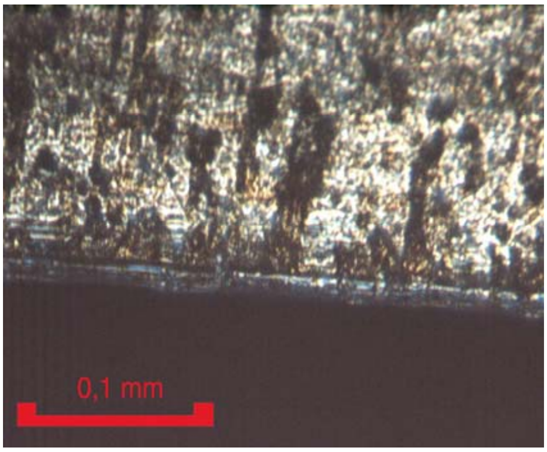


Fig.3. Cross section of a silver layer obtained by a pulse current; current pulse density = 100 A/m^2, t_p = 5s, t_0 = 1s

Figure 4. gives galvanic bath voltage change in time during the gilding process using pulse current density of 120 A/m^2 with a pulse duration 7s and a pause duration 1s. For clearness, here are given only four pulse-pause cycles, while all data are stored in suitable file and they can be used for presenting in arbitrary way.

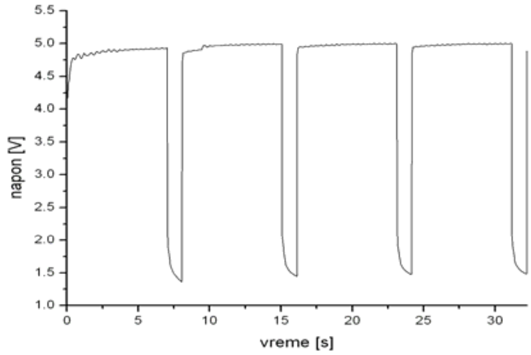
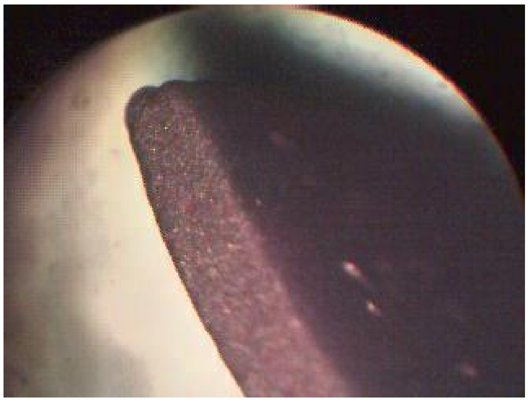
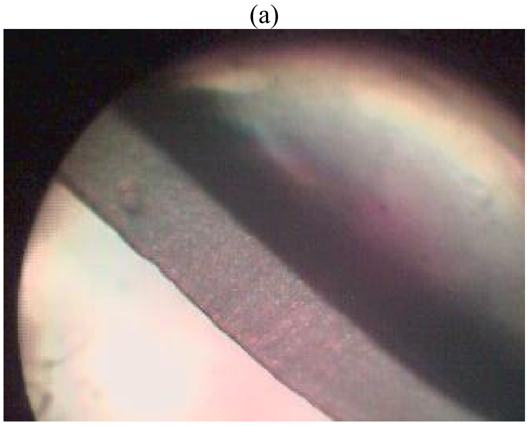


Fig.4. Voltage change during deposition of gold in Hull cell using current density of 120 A/m^2 with a pulse duration 7s and a pause duration 1s

The advantages of well-led pulse-reversed regime are also shown in the case of copper layer deposition on a steel substrate. Figure 5. gives a shot of a sample whose sharp edges are impossible to track by a direct galvanization. Much better result is accomplished using pulse current.



(a)



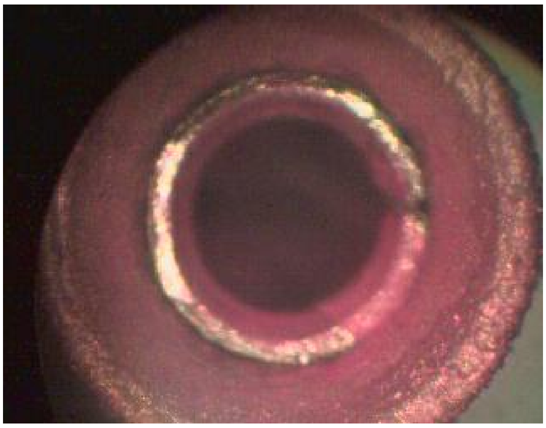
(b)

Fig. 5. Edge effect: (a) using direct current; (b) using reversing current.

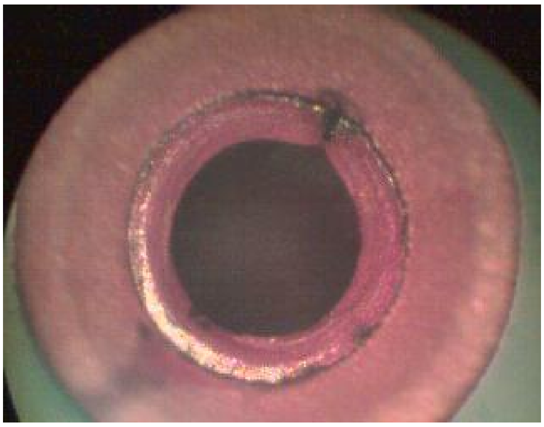
Need for forming quality layer represents very important demand in manufacturing process and especially testing VLSI circuits. The most important element when testing a component is binding a component which testing, so-called DUT, to a testing device. DUT configuration, architecture and the ability of testing device and testing role determine an optimal use approach [14]. Therefore, it is worked on projecting and manufacture of persistent adapters, so-called pin cards, which are being projected for testing of several different elements and represent a complex totality, which in a phase of projecting and manufacture in fabric could be very hard work. Characteristics of every reliable adapter are: transparency, simplicity, persistency and safety. These features are normally also related to the purpose of the adapter.

The saturation of DUT (device under test) and a signal distribution towards input and output pins are guided through interface adapter. Required power for testing of VLSI circuits can be either in miliwats [mW] or for testing of PC cards in wats [W], and the signals on pins reach frequencies of order of several GHz. Functional testing requires such grounds and connectors which provide from a few dozens to several hundreds of contacts towards component which testing, that is for saturating of DUT. Pins and connectors must have their own duration period of time and reliability during their exploitation. Therefore, the forming procedure of quality layers in manufacturing process is of great importance, in concrete case in forming pins of integrated circuits.

A copper-plated pin of a ground of an integrated circuit is shown in Figure 6. The layer obtained using pulse-reversed current is of much better quality (example on Figure 6[b]) in comparison to the layer obtained using direct current of same density and the same electrolyte (Figure 6[a]).



(a)



(b)

Fig. 6. Copper deposit obtained on relief surface: (a) using direct current; (b) using reversing current

C. Process modeling

Electrochemical processes which are observed belong to class of reactions which are successfully modeled by an equivalent electrical circuit shown in Figure 7. In this paper, the parameters of model obtained for reaction of gold deposition using pulse current density of 120 A/m^2 with pulse duration 7s and pause duration 1s are determined. In this case, voltage response of galvanic bath is shown in Figure 4. Values of model parameters which are used for successful simulation of experimentally obtained diagram in Figure 4., are: Ro = 0,1 Ω, R1 = 11 Ω, R2 = 12 Ω, R3 = 5,15 Ω, C1 = 6 mF, C2 = 245 mF.

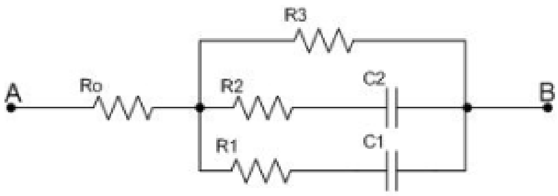


Fig.7.Equivalent electrical circuit for observed class of electrochemical reactions

Simulation is performed in program package ORCAD, and the simulation result is shown in Figure 8. Shown diagram gives very good agreement to a real curve from Figure 4., which means that chosen model very good describes observed process in quasi-stationary regime. Qualitative analysis provided in that way allows determining optimal length of pulse and pause duration, without performing a real experiment, but on the basis of assigned criterions, which could in this case be stationary state reaching in a pause period. Using appropriate software, a system could be realized which would automatically regulate pulse and pause duration for every real system, following earlier defined criterions.

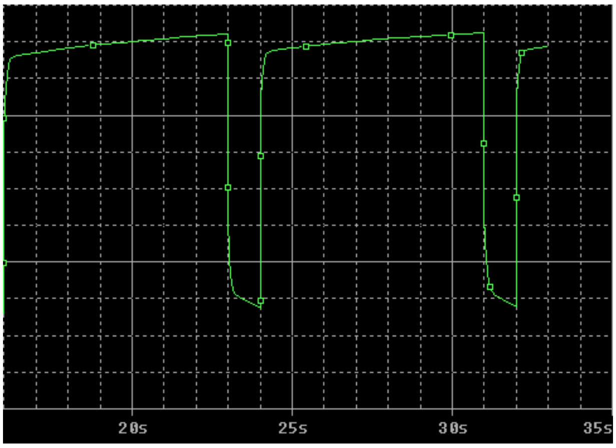


Fig.8. The simulation result is performed in programme package ORCAD

III. Conclusion

Quality layers of gold, silver and other precious and non-ferrous metals which are of great importance in industry of fine electrical components, can be obtained by using pulse current with optimal parameters. It is possible to reach and regulate those parameters using computerized systems, if an adequate model of process which takes place in galvanic bath is assumed. This paper describes modeling of these processes with calculated parameters and also shows successfully performed simulation of galvanic cell voltage response. The advantage of pulse-reversed regimes is experimentally proved when they give uniform layer thickness, radiance, adhesion and substrate sharp edges tracking using examples of silver, gold and copper layers.

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