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OPTIMIZATION OF VARIOUS PARAMETERS IN GOLD ELECTRODEPOSITION FOR MICROELECTRONICS

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Abstract— **Electrochemical deposition is a method for obtaining metallic coating on surface by precisely controlling current and voltage over two electrodes in a plating bath. In the present research work, electrolyte Au has been deposited on Al alloy specimen by high speed cyanide based electroplating bath with Direct Current(DC) and Pulse Current(PC). This study reports the effects of deposition of gold on Al alloy with standard DC and PC mode. All the parameters affecting the electroplating bath like gold concentration, pH, temperature and current density are studied. It has been observed that the fine finishing of plating as well as fine grained structure of Al alloy specimen is obtained with PC as compared to DC. The sample is characterized by SEM to confirm the above morphology of surface. The replacement of DC by PC in the electrodeposition of gold has a remarkable effect in improving the mechanical properties of the deposits and in reducing their internal stresses. Deposit with finer grain is obtained with PC because current density is considerably higher as compared to DC which increases nucleation rate. PC is more effective in maintaining a uniform composition over the thickness of the deposit than DC plating. For many important applications in the electronic industries PC plating offers considerable advantages due to its remarkable effect.**

Keywords— Al alloy, Au electrolyte, DC plating, Electrodeposition, PC plating, Microelectronic devices, SEM.

I. INTRODUCTION

Microelectronics is an interesting branch of electronics which find various applications in telecommunications, military services, medical field, and automatic control systems. It operates at high frequencies, which require gold de- posits which are highly pure, dense, conductive and smooth. Electrically conductive coatings produced by electroplating are commonly used for enhancing the surface properties of base ma- terial. The surface enhancement is caused by many factors, in- cluding increase in hardness, higher conductivity of plating compared to substrate, prevention of insulating film formation, corrosion, and reduction in mechanical wear. In general, the per- formance of electroplated coatings is determined by a broad va- riety of interacting variables, such as metal/alloy, substrate/ un- derlying metal(s), substrate finish, thickness, and operating conditions.

Gold plating, a technique used for evenly coat- ing items with deep cavities, such as microwave components, irrespective of shape and size of the item to be plated, is used in this work to coat radio frequency components. Gold plating is carried out for various engineering properties on Aluminum 6061T6, Kovar, Invar, and SS 304. In this work, a process se- quence is developed for gold plating on aluminum base material with autocatalytic nickel as the undercoat. Acidic Gold Cyanide plating chemistry [KAu(CN)2] is used owing to its better plating rate, high current densities, uniform deposit distribution and stability. The quality of gold plating is controlled by gold con- centration, pH, temperature, current density, mechanical agita- tion, anode cathode ratio etc. The influence of these variables is studied under different process conditions. Hence the present study is to investigate the effect of these parameters on plating surface finish. Gold is one of the most commonly used precious plating materials for high performance electrical contacts. Pure gold is very soft. When using gold as plating material, one of the limitations to their lifetime is the wear resistance of the plating material. Hard gold is usually used in order to improve the wear resistance of gold plates. The high degree of hardness is achieved by alloying elements such as cobalt, iron or nickel. However, the effect of alloying elements is limited by the gal- vanic process and other surface properties, which are also re- quired for microelectric devices. Our study investigates a new way of modification of gold plates. Instead of alloying elements, nanoscale particles are used for the modification of plating. The reason for depositing nanoscale particles is based on the fact that the hardness of pure gold is about HV 70 and the hardness of hard gold is about HV 170.

The use of pulsed current is well known as a research tool for studying the electrodeposition mechanism of metals. With in- creasing emphasis on the properties of the deposits, however, it is realized that this method of deposition could well provide a means of improving their properties. It has also long been known that the structure and surface roughness of gold and gold alloy deposits can be influenced by periodically reversed or pulsed current, but this interest developed greatly when it is realized that pulse plated gold deposits proved superior to D.C. plated deposits for certain electronic applications. The pulse plating technology would provide

ample research opportunities not only to gold plating industries but also for a wide variety of industries namely electronics, aerospace applications, ship building and automotive industries. In these industries pulse plating technology has been in existence for a decade. However, they face many problems. Recently, with the advent of nano-technology, the process could be further extended to achieve nano-structured coatings that might find application in the development of nano-structured coatings. To this date, pulse plat- ing does not find wide application in the common industries be- cause of the higher investment cost (mainly due to the rectifier) compared to dc plating and lack of proper understanding of the process parameters. Although pulse plating is used to plate cop- per and gold initially, the survey shows that extensive work on other metals such as nickel, chromium, palladium, zinc and sil- ver has also been done. Although the manufacturers of pulse rectifier may give recommendations on choosing the parame- ters, for plating of a specific material, one may have to do exper- imental studies to identify the optimum parameters. In the present study, a systematic investigation of gold deposition from an acidic cyanide bath has been undertaken with the appli- cation of DC and square wave pulse current.

II. PROCEDURE

A. Experiment design

The bath parameters like metal concentration, pH of the bath and temperature of the bath are major components that affect the plating quality. Hence the present study is aimed to investi- gate their effect on plating surface finish. Design Expert Soft- ware (DX7) is used to derive different 20 set of parameters to conduct trails covering entire range. Aluminum 6061T6 alloy samples of 25x40x2mm are used for experiments. The ranges of parameters reported in various published articles [1],[2],[3] for Gold plating on Aluminum 6061T6 alloy are given Table-1.

Table-1: Plating bath parameters

Sr.	Parameters	Range considered for Optimization
1.	Gold concentration	6.0 g/l – 15.0 g/l
2.	pH of the bath	3.3 – 6.5
3.	Temperature of the bath	40°C – 70°C

Thickness of the deposit is estimated using the formula:

$T = (w \times 10000) / (d \times \text{area})$ microns

Where ‘w’ is the weight electrodeposited, ‘d’ is the density of gold.

$w = (Iav \times t \times \text{atomic weight})/(96500 \times \text{valence})$

Where ‘Iav’ is the average current and ‘t’ is the real time in sec- onds.

The acid hard gold rapidly become the finish of choice for mi- croelectronic devices. It has been intensively developed for op- eration at very high current densities; also for uniform deposit distribution and for compatibility with various types of selec- tive plating apparatus. These electrolytes are based on mixtures of weak organic acids and their salts. Depending on the choice of electrolyte, the metallic brighteners are added in simple, complexed, or chelated form, together with surfactants, range extenders and depolarizing agents, as needed. Platinized tita- nium grills are used as anode. Teflon based immersion heaters are used for uniform heating. Bath is continuously filtered with 1-micron particle filter pump to keep solution free from any particles. The output of the DX7 with parameters for 20 sets cov- ering the ranges and their results are evaluated. All the samples are plated with standard DC power supply. From the results the following points are concluded. The surface finish quality is mainly dependent upon pH of the bath. The quality of the sur- face finish degrades with decrease in pH below 4.9. Semi-bright surface finish is achieved at pH above 4.9. Hence close control of pH is important. Better surface finish is achieved consistently with gold concentration at 10.6 g/l.

B. Effect of pulse power supply on plating finish

To understand the effect of PC parameters like Forward ON time and Forward OFF time on plating finish, some samples are gold plated at different sets of parameters which are set in such a way that average current density constantly remains 2 am- peres per square feet(ASF). From the results it is observed that best cycle giving bright finish is with Forward ON 1ms and For- ward OFF 10 ms. [4],[5],[6].

Constant current 2 ASF is set for standard DC power supply, and a cycle of 1 ms ON time followed by 10 ms OFF time with 20 ASF current is set in Pulse Power Supply for plating the sam- ples. The temperature of the bath is maintained at 65 °C. The process is kept under at constant current mode.

To understand and compare the gold plating surface quality plated with standard DC power supply and pulse power sup- ply, different samples are plated by keeping all the parameters constant except current for given selected set of samples. From the results it is observed that pulse plating gives better surface finish as compared to DC.

C. Effect of pH on plating finish

From earlier experiments it is observed that the quality of the surface finish degrades with pH below 4.3 and above 5.7. Fur- ther to optimize the pH parameter, following samples are plated at different pH ranging from 4.3 to 5.7. Results shows that as pH is increased, gold deposition rate and brightness in- creases up to pH value of 4.7. But after that it remains constant up to pH value of 5.1. After that gold deposition rate

decreases by pH value of 5.7. Hence close control of pH is important.

D. Effect of Gold Concentration on plating finish

A set of samples are exposed to gold solution with concentra- tion ranging from 7-14 g/l for the optimization of gold concen- tration. Pulse current is given with parameters FORWARD on: 1 ms, FORWARD off 10 ms, with current density of 20 ASF [4]. It is evident that at same pH and temperature with variable gold concentrations, plating finish is different. From the results, it can be concluded that bright surface finish of gold plating is achieved with gold concentration ranging from 10-12 g/l.

E. SEM characterization of plated specimen

Both DC and Pulse plated specimens are subjected to SEM mi- croscope for particle size analysis. It is clearly evident from fig. 1 that pulse plated sample is having smaller particle size (in the range of 400 nm), as compared to DC plated sample (in the range of 1200 nm).

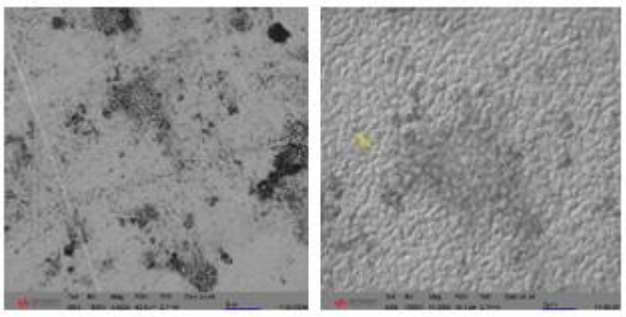

Fig. 1 (a) DC plated sample, (b) PULSE plated sample

III. CONCLUSION

From the results obtained it is observed that the parameters shall be controlled closely with narrow band width. pH of the gold plating should be maintained very closely within 4.9 ± 0.5, since the variation in this parameter has greater effect on the plating surface finish. Though the variations in temperature has not shown much deviation on the plating surface finish, it shall be maintained within 65 ± 1°C. The gold metal concentration may be maintained in the range of 10.6 (+0.5 & -1.5 g/l). Pulse plating may be adopted (Forward ON-1ms; Forward OFF- 10ms; 20 ASF) for repeatability and better control over plating surface finish. From this work on the pulse plating of gold has shown that it is possible to obtain deposits having properties which are superior to those of deposits obtained by normal D.C. plating. This method also makes possible the production of nearly stress free deposits, while it also seems to furnish better micro throwing power of the electrolytes.

IV. END SECTIONS

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