<研究論文>

Strip형 반도체 부품상에 회전음극 방법에 의한 주석도금에 관한 고찰

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Rotary Cathode Tin Plating on Strip Type Semiconductors**

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Abstract

A novel electroplating process is described and effects of anode lay-out on thickness distribution and on plating rate are discussed. Microphotographic analysis indicates deposits are compact and less "POROUS" than of barrel and rack. With this process production cost reduction and capacity increase could be achieved by a rate of 60% and 97% respectively, as compared to our present barrel plating process. This process disclose a number of beneficial processes such as color coding system on TO-92 package and development of a new tin bath formula.

초 록

회전음극을 사용하는 새로운 도금방법을 설명하고 양극배치가 도금층의 두께와 도금속도에 미치는 영향을 검토하였다. 현미경조직도 분석하였으며 도금층은 견고하고 barrel이나 rack도금방법에서 보다 기공이 적었다. 이 새로운 도금법을 쓰면 barrel도금법에 비하여 생산비 절감이 60%, 용량증가가 97% 달성될 수 있었다. 이 도금법은 TO-92 transistor package표면에 color coding을 정확히 할 수 있고 저렴한 새로운 주석 도금욕을 개발할 수 있는 등 여러가지 유리한 점이 있음을 나타내었다.

1. Introduction

This project has been undertaken so as to enhance plating efficiency of TO-92 transistor and resulted in substantial improvement of productivity and plating quality on plating of the strip type substrate. For this purpose we were derived along to design the said Rotary Cathode Plater-19 (called RCP-19 see Fig. 1), a combination of barrel plating mechanism with rack to ensure steady current flow and uniform metal distribution over all the plating load to be plated.

In a given barrel plating load the plate thickness varies from part to part and the distribution of thickness is a statistical variable which must be properly overplated to meet minimum thickness specification. Nanis'es data (1) show that for typical solutions that maximum current density is ten or more times than the average current density and that most of the current is concentrated in the outer 20% of the load, so the excess waste of tin has been encountered in barrel plate.

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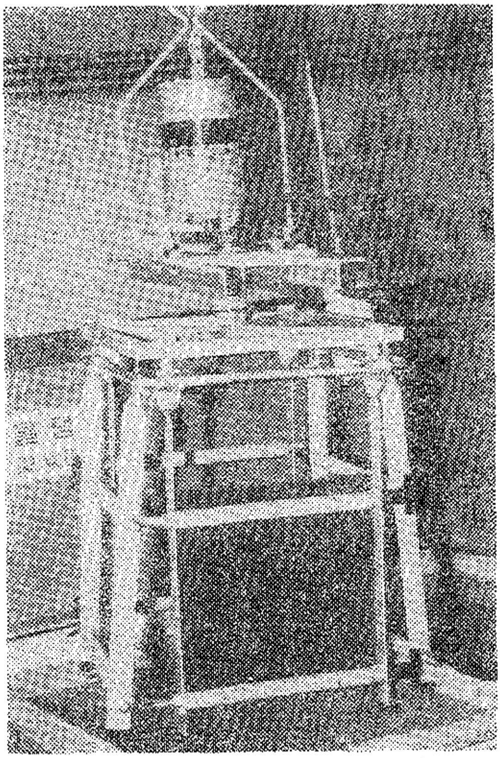


Fig. 1 RCP-19 set loading 4 racks.

Therefore many attempts of barrel modification such as "tumbling wen" (2) have been made in our barrel plating process to avoid over plating. However, the troublesome of useless tin consumption has not been overcome until the use of this RCP-19.

With RCP-19 we were able to reduce production cost by enhancing the plating quality and by avoiding rework (replate) which consumed uselessly in additional chemical refreshment. Furthermore, this process with the capacity increase provides us to supply and cover all plating demands of Fairchilds strip typed semiconductors. With application of this advanced plating process into our plating line, in addition to plating quality increase, other profitable processes such as color coding on TO-92 package and new tin-bath make up become feasible.

2. Theoretical Approach to the Rotary Cathode Electroplating.

As an electrochemical apparatus, a rotating sphere, a rotating disk and rotating ring-disk have been employed in the past as an important electrode geometry in electrochemical research such as the investigation of the double-layer structure (3) Rotating process have been proposed a new potential tool in studies of mass transfer and reaction kinetics in electrochemical systems(4).

The rotating mechanism has not been popularly used in large scale plating production line, especially in the tinplating of Semiconductors device. The present interest in rotating cathode electroplating process alluded from the fact that the mass transfer and current distribution characteristics of the rotating mechanism exhibits an uniform limiting current distribution (5), and the stirring effects on to increase current efficiency (6). When even rotating happens it is evident that the process is controlled by diffusion which is speeded up by agitation.

Law (7) appreciated this long ago. The diffusion layer may be as much as 0.05 cm thickness. The most effective way to speed up the diffusion is to rotate electrode so that maximum shear occurs nearest the metal-liquid interface.

The limiting current density in the presence of large excess of supporting electrolyte is given (8) for a simple metal deposition by

$$I_L=ZFD\frac{dC}{dN} \cdots\cdots\cdots\cdots\cdots\cdots (A)$$

Where Z is the valence of the deposited metal ion, F is the Faraday constant, and D is the diffusion coefficient, and dN is the thickness of diffusion layer. C is the difference in bulk concentration and concentration at the metal-solution interface. In a stagnant (still) bath without having a circular flow of electrolyte the diffusion layer is to be considered to extend infinitely into the bulk electrolyte.

Also, with the Levick's equation under mass transport control (9),

$$J_L=0.62D^{2/3}, k^{-1/6}, O^{1/2}\ C \cdots\cdots\cdots\cdots (B)$$

$$dN=1,613D^{1/3}, k^{1/6}, O^{-1/2} \cdots\cdots\cdots\cdots (C)$$

Where J_L is the limiting mass transport rate in moles/Cm^2-sec, D is the diffusion coefficient, k the kinematic viscosity, O the angular velocity (2πrps), C the bulk concentration.

Considering on the foregoing equations A, B and

C, those I_L and J_L increase *linearly with the metal* ion concentration in the bulk solution, C, and inversely proportional to the limiting diffusion boundary layer, dN.

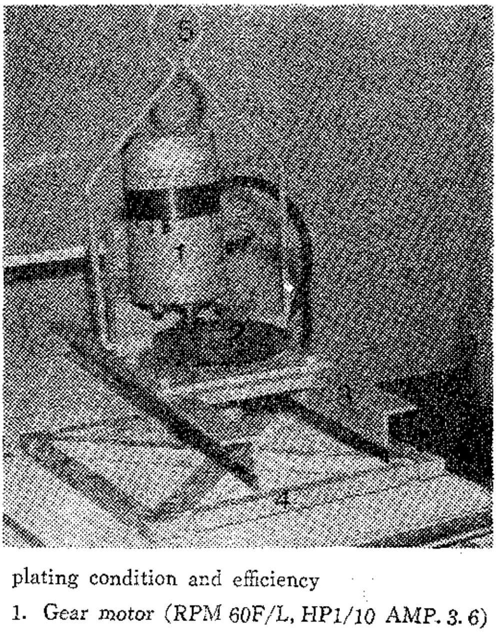
The rotation of electrode (cathode) will decrease the thickness of diffusion layer so that I_L and J_L will increase due to the resulting increase in the concentration gradient *at least for a limitted range of* rotating R.P.M. This relates in other words with the increase of throwing power and covering power.

On the basis of this theoretical discussions it would be expected that the rotating cathode electroplating mechanism so prefers to the stationary process (rack process) even in large scale production for the better electrodeposition rate.

3. Mass Evaluation with RCP-19

The present RCP-19 is designed based on the forementioned theory that would characterize the rapid and uniform metal distribution.

A RCP-19 set divides into two main parts, a rotating holder part (**Fig.** 2) which is consisted of 5 subparts and the rack which is below the rotating holder. The latter consisted of 4 racks imitated the shapes of the Swiss plating Corp. Ltd's rack, *FSC (HGKG)'s rack and **GSEC (KOREA)'s rack.



plating condition and efficiency

1. Gear *motor* (*RPM 60F/L, HP1/10 AMP. 3. 6*)
2. Gear (70 teeth, plastics)
3. Motor supporter frame (steel)
4. Rotating rack-holder frame (brass)
5. Hoist hook.

Fig. 2: Rotating holder (RPM 15)

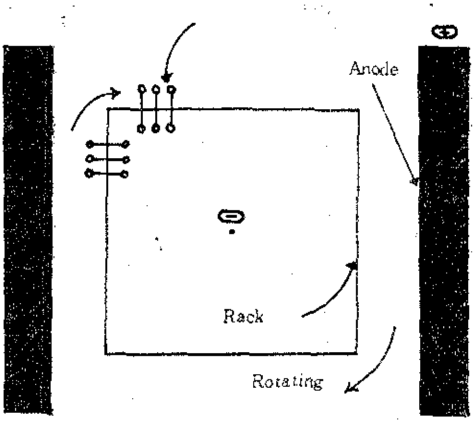
Experiments to check the thickness distribution were performed with following five groups mainly chainging (**A, B, C, D group**) the anode lay-out in plating bath, and plating condition (E **group**) for the comparision of barrel plating with the present RCP-19. Experimental conditions used in **A, B, C, D group** anode layout are presented in **Table** 1 and **Fig.** 3, 4, 5 and 6.

Table 1. General bath Condition

Starter/Brightener Supplied by (Leo Ronal) refreshment, 50cc, 30cc/100A. Hr respectively.
Tin cont. ……………………2. 5±2 *OZ/Gal*
Sulfuric acid cont. ………12. 3±2FL. OZ/Gal
Temp. ……………………15±1°C
No solution circulation
Load size……………………20K (3200 in^2)

A Group

TO—92 Frames oppositely jamed between beads.



plating condition and efficiency

183A±8A/2. 5V/15min.

Cathode area, *3200* in^2 (*20K*)

Anode area, 2464 in^2

Plating efficiency, *** 80. 3%

$$^{***}\left(\frac{\text{Actual deposition on frames(WT)}}{\text{theoretical (WT)}}\times 100\right)$$

Fig. 3: A schematic, plan view of plating bath anodes lay out in 2 directions.

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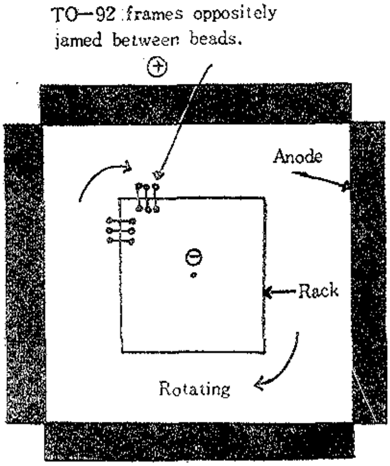
B Group



plating condition and efficiency

190A±5A/2.5V/15 min.

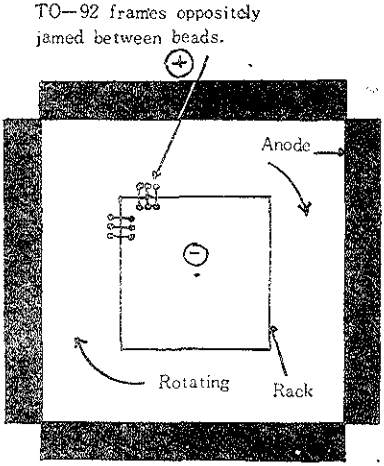
Anode area, 4144 in^2

Cathode area, 3200 in^2 (20K)

plating efficiency, 87.3%

Fig. 4: A schematic, plan view of plating bath for utilization of the novel RCP-19. Anodes lay out in 4 directions.

C Group



plating condition and efficiency

220±5A/2.5V/13 min.

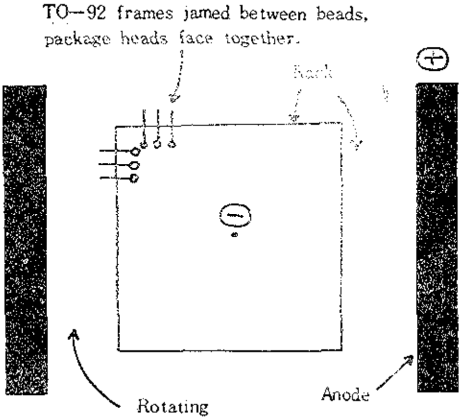
Anode area, 4144 in^2

Cathode area, 3200 in^2 (20K)

Plating efficiency, 89%

Fig. 5: A schematic, plan view of plating bath for utilization of the novel RCP-19. Anodes lay out in 4 directions.

D Group



plating condition and efficiency

185A±5A/2.9V/7 min.

Anode area, 2464 in^2

Cathode area, 1600 in^2 (10K)

plating efficiency, 91%

Fig. 6: A schematic, plan view of plating bath.

E Group

Barrel plating was employed for the comparison with RCP 19.

Fig. 7: 7-A Tinned surface view of TO-92 frame by Barrel tin-plated in. (100×) 7-B Tinned surface view of TO-92 frame by RCP-19 (400×)

Experiments were performed in following conditions of 170A±10A/6V/20min, anode area 2464 in^2 (the same lay out of anode as in **D group**) and cathode area 2400 in^2 (15K), while others were the same.

The tin deposition onto TO-92 frames achieved by barrel plating showed normally of irregular surface or rough, and has a number of scratches due to unavoidable tumbling effect (**Fig. 7-A**)

However with RCP-19 the deposition was smooth and uniform (**Fig. 7-B**)

4. Results and Discussions

Table 2. Thickness distribution data.

Exp-group	Measured point	Average thickness	Standard deviation	Plating efficiency factor (min. thic. x lot size/ max. curr. x time)
A	Upper	161 microin.	55 microin.	0.803
	Middle	163 〃	48 〃	
	Lower	165 〃	55 〃	
B	Upper	165 〃	46 〃	0.814
	Middle	165 〃	46 〃	
	Lower	170 〃	47 〃	
C	Upper	177 〃	50 〃	0.944
	Middle	183 〃	45 〃	
	Lower	180 〃	57 〃	
D	Middle	232 〃	57 〃	1.316
E	Middle	215 〃	83 〃	0.550
Rack plating based on FSC (HGKG), WW 14-21, 74	Middle	150 〃	35 〃	(plating time 8 min current 185A±5) 0.756

As can be noticed in **Table 2.** those plating efficiency factors of RCP-19 shows superiority to barrel plating and rack. Togeder with low bath voltage, noticed in **Fig. 3～6,** this high plating efficiency factor was considered to be obtained on accounted of the decrease in overpotential and the resistance of electrolyte, for bath voltage, V may be expressed as equation (D)

$$V=(E_{rev.})_a+(E_{rev.})_c+\eta_a+\eta_c+iR \cdots\cdots\cdots\cdots\cdots\cdots \text{(D)}$$

where $(E_{rev.})_a$, reversible equilibrium potential of anode; $(E_{rev.})_c$, reversible equilibrium potential of cathod; η_a and η_c are overpotential in anode and cathod respectively; R is the resistance of the electr-

Table 3. Performance on plating quality, capacity and chemical usage rate.

Item	Barrel(WW18-52 '74 1-8 '75)	RCP-19	Performance
1. Capacity increase K/2 baths/shift	$\frac{60}{22}\times 32K\times 7.1hr\times 0.85$ (physical effic)=527	$\frac{60}{15}\times 40\times$ $7.1\times 0.85=966$	1. 96.6% increase
Work hour; 7.1 hrs			
Max. load size;	16K/barrel (12″×10″)	20K/RCP−19	
Plating time;	20 min	13 min.	
2. Quality			1. Conversion of inspection mode.
Lot reject rate %	1.0−3.5%	0	
Over plating rate %	0.1−10%	0	2. Thickness uniformity.

Item	Barrel(WW18-52 '74 (1-8 '75)	RCP-19	Performance
Average thic. Thic. deviation	180—220 micro in. 70—90 micro in.	160—180 40— 60	3. Cost reduction by reducing rework $ 25/KK
3. Bath refreshment			1. Cost reduction by reducing chemical usage $ 58. 93/KK
Tin usage (CC/K)	0. 025	0. 012	
Starter (CC/K)	12	11	
Brightener (CC/K)	6	3	

olyte.

From the foregoing conclusive evidences, it can be seen that the company's specification minimum thickness 100 micro in. can be plated in a short time span of from around 12 min., a result which never be achieved with the barrel or stationary rack plating process. Uniform metal distribution also resulted in reduction of tin usage with this process.

5. Conclusion

On the certain evidences from en-mass test results, the definite conclusion can be drawn that immense productivity (96.6%) and production cost reduction (by $ 83.94/KK in case of TO-92 transistor's tin plating) can be produced by this RCP-19 plating process as compared to present barrel plate.

In reviewing the plating efficiency factors, corresponding to the throwing power of RCP-19 plating showes its outstanding results when total average current density of cathode flows higher than 10A/ft^2).

Other profitable processes, in addition to capacity increase and plating quality performance, the color coding, change of quality inspection method, (total inspection method changed to spot inspection) new tin plating bath make up, and the elimination of solution circulation by means of filtering will be able to be established in TO-92 transistor assembling. The plating process out lined in this report will offer a new approach to metal finishing of Semiconductors.

It has the potential to be applicable to a great variety of the shape of substrate to be plated with tin or other metals.

And for the installation of this RCP-19 plating system, in our plating line existing tanks and equipments are still available without big modification.

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〈저자 소개〉

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