〈技術解說〉

Metal Deposit Distribution in Barrel Plating of Partially Conductive Load

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要 約:

IC전자부품 중 DIP계 종류를 바렐을 사용하여 주석도금 할때에 그 전착현상을 조사하여 부분전류의 동태를 설명할 수 있는 변화인자를 알아보려 하였다.

DIP와 같은 모양인 IC부품은 부분전도체로 구분되어지며 그 전착상태를 one-dimensional model로 분석하였을때, 가입전류밀도, 바렐의 회전속도, 용액중 금속이온 농도와 깊은 관계가 있음을 보인다.

다공질과 같은 것으로 간주한 one-dimensional model로서의 이론식은

$$J=\frac{\delta'}{\beta}\left\{-\frac{c^s}{\gamma}\exp-(1-\alpha)n\phi\right\}$$ 로 표현된다.

Abstract

The metal deposition behavior in the barrel tin plating has been studied for the electronic DIP products, and tried to find out some modified factors in order to explain partial current flow behavior of this load.

The deposition distribution characteristics for DIP products should be classified with the normal barrel plating as partially conductive load.

Deposit distribution curves obtained from one-dimensional model have shown strong dependence on the applied current density, rotating speed of barrel and metal ion concentration of the solution.

Theoretical formula $J=\frac{\delta'}{\beta}\left\{-\frac{c^s}{\gamma}\exp-(1-\alpha)n\phi\right\}$ derieved from one-dimensional porous model has been proposed for the barrel plating behavior where higher overpotential and concentration changes take place during barrel plating.

1. Review:

Barrel now becomes widely used in the plating industry and along in the chemical engineering processes in the treatment of great numbers of small parts owing to its ease and extensive vasatility.

There are various sizes available in the

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market, but not too much changes in apparent feature or the shape.

Even the current contact method still holds to the old longaged process, say, the traditional dangler or center-rod.

There have been published a few papers dealing with the statistical description of the meatl deposit distribution but very few for the interpretation on the individual electrochemical reaction at a specified location in the rotating barrel.

Especially, it has not been subjected for the barrel plating behavior of the Partially Conductive Load such as C-Dip or P-Dip products.

Theoretical model of barrel plating·was proposed first by L. Nannis 1971, assuming the dispersed load in the solution in the rotating barrel to be on the analogy of giant porous electrode.

Predecesors of those theoretical reviews used for their studies metalic substrates, ie., Completely Conductive Load, with shaped of cylinder.

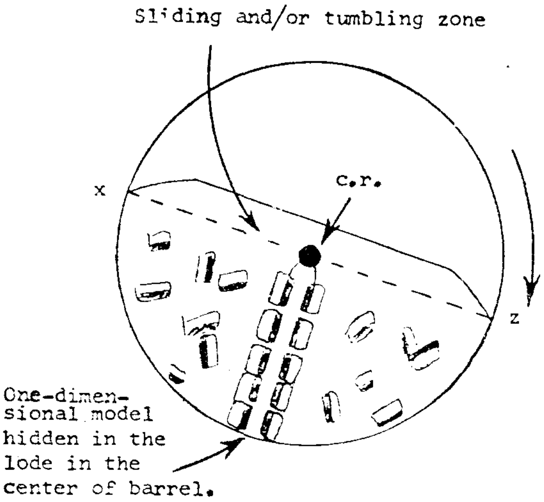


Fig. 1-1(a) Schematic cross-section of rotating barrel, General feature of a barrel (B) rotation at RPM 2.5-5.

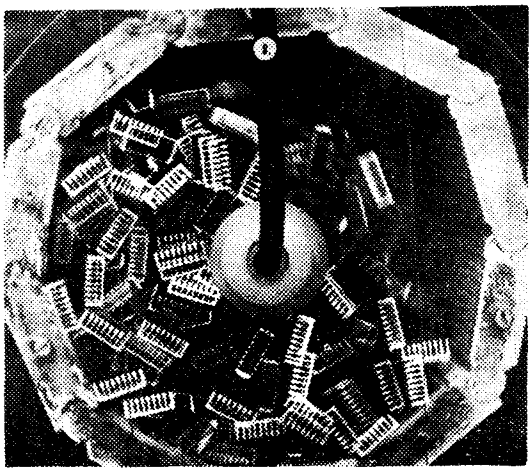


Fig. 1-1(b) Side view of rotating barrel (8″×12″) at RPM 2. 5. with Load volume, 2000EA C-Dip.

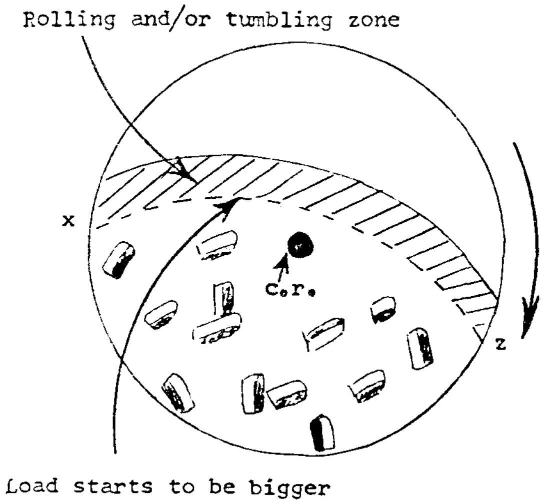


Fig. 1-2(a) Schematic cross-section of a barrel (B) rotating at RPM 6-13.

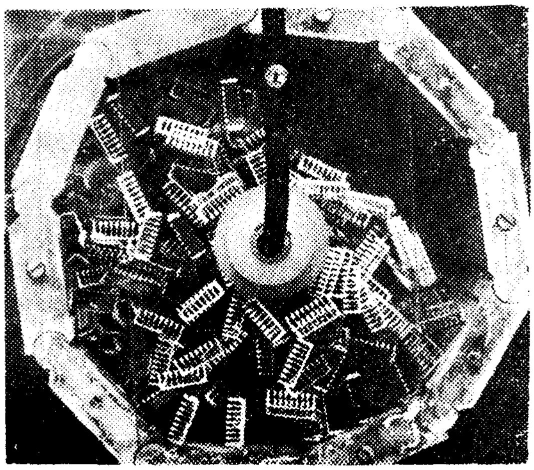


Fig. 1-2(b) Side view of rotating barrel (8″×12″) at RPM 7. Load volume, 2000EA C-Dip.

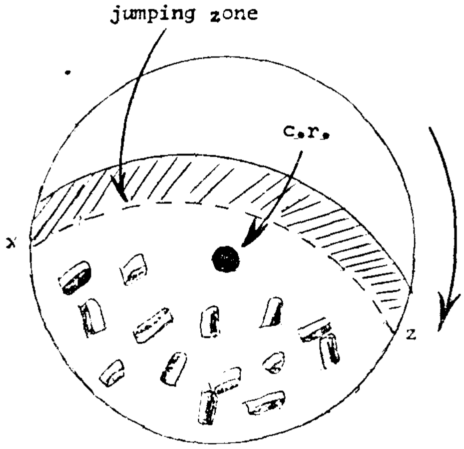


Fig. 1-3 (a) **Schematic cross section of rotating barrel (B) 14-20 r.p.m.**

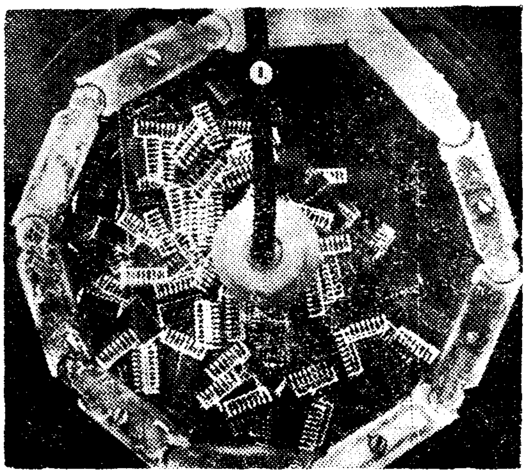


Fig. 1-3 (b) **Side view of rotating barrel (B) at r.p.m. 20**

sphere, cylindrical tube, eyelet and driving screw etc.,

For some of the electronic DIP products might be expected different behavior in the metal distribution, compared to that of the normal conductive load. Since they are composed of from metalic leads and nonmetalic material like ceramic or plastic, so that electrical current can't flow further consistently, thus leading to that there remains still considerable parts not being attended in the electrodeposition reaction.

Furthermore, at any particular instant in higher RPM over 20 (in the barrel 8″×12″), many of parts are shielded from the anode by the parts or ceramic body, and hence receiving little or no plating current. Hence, to such C-Dip parts in the barrel plating operation is given the name of partially conductive load (PCL).

The purpose of this editing work is to give some ideas to platers, by investigating experimentally the appropriate region of barrel plating conditions with ordinary barrel to reduce chemical usage together with metal ingot by improving plating quality as well as barrel plating efficiency, on the other hand, to develop an innovative barrel plating model or the design.

Table 1: Current efficiency and mixing rate of CCL of C-Dip products.

RPM	2	12	22	32	42
Current Effi.	48.8	48.0	44.7	39.7	34.1
Mixing Ratio*	0.44	0.48	0.52	0.56	0.63

* Mixing rate means the value of relative deviation at each RPM concerned.

Plating Conditions: C-Dip 14-leads, barrel: 9″×6″, current density 6.2 A/ft^2 (15Amp)

2. Discussions and Results

2.1 Barrel RPM and metal spread onto part to part.

Transparent plastics side wall was installed in the barrel for understanding of those predominant processes that controls mixing rate, current efficiency and the deposit distribution of the electrochemical reaction rates within rotating barrel having with C-Dip units.

Upon observing of the load rotating at slower RPMs it is found both loads of PCL andCCL of C-Dip products respectively makes a similiar configuration as half-moon shape during rotating and then changes into "o" letter form over the RPM of 14.

The load becomes loosely packed.

At such higher RPMs mixing rate not enhances for the higher RPMs but it tends to decrease.

As observed in Pictures above, the higher rotation speed leads to reduce the probabilites of contacting each other part to part or part to current contact, so that barrel plating efficiency turns to be worse compared to the CCL case (See the tables-1,2).

Furthermore, due to the partial conductivity characteristics of the subject there are lot of parts merely passing through the solution and not making electrical contact with between neighbor or center rod.

These parts can display bipolarity and the anodic portion of the parts cause problems such as unplating or displating

The C-Dip parts rotate with the barrel along arc "xz" in Fig. 1 until they reach at the top of load x, and from this point they are going to be either sliding, tumbling or jumping down to the suface of the load, beneath and afterwards those C-Dip parts keep rotating along are "xz" being stationary with respect to the barrel until it reaches point x, receives only charge transfer current for the deposition.

However, due to limitation of contaction from part to part it may be expected the current distribution in the PCL C-Dip load to be worse.

Current efficiency of PCL decreases in direct proportion to the increase of rotational speed of the barrel, while that of CCL C-Dip system generally showes different results, ascending as the RPM increases.

Thereafter, to achieve plating cost reduction and to enhance plating quality have to consider simultaneously in both factors current efficiency as well as the current density distribution without sacrificing them.

Remarkable turbulence in current flow has been observed in the field operation of C-Dip barrel plating, for some or many of the parts are shielded. When the lower unperage indication of the ampere meter appears at, the it means some part of applied current, available for other irresivable phenomena, concentrates at the center rod.

So is in higher RPMs, the current would be consumed on the center rod intensively due to the loosely packing of the load as shown in following table 3.

2. 2 Metal Distribution in One-Dimensional Model.

Whatever plating method is employed, barrel

Table 2: Barrel Plating results of PCL C-Dip load according to the RPM variation (Barrel 6″×9″)

R.P.M	Barrel Plating Efficiency (%)					Mixing Ratio**			
	Sn^{++} : 0.083M		Sn^{++} : 0.212M			Sn^{++} : 0.083M		Sn^{++} : 0.212M	
	15A	50A	15A	30A	50A	15A	50A	15A	50A
0	65.80	63.54	62.40	85.69	87.67	0	0	0	0
6	70.74	82.95	53.38	78.52	83.13	0.48	0.67	0.40	0.59
13	69.08	75.69	43.01	—	79.13	0.45	0.68	0.45	0.61
20	65.75	73.13	43.22	—	73.89	0.45	0.67	0.40	0.60
28	62.50	66.75	43.00	—	64.13	0.44	0.67	0.40	0.61
36	55.95	63.94	37.50	—	60.00	0.40	0.67	0.40	0.61
44	34.83	59.34	37.50	60.05	58.40	0.23	0.60	0.35	0.48

** Relative deviation of deposit distribution for each RPM compared to that of that 0 RPM.

or rack distribution of deposit is determined by the lines of current flow at the load surface. In barrel plating, distribution is caused by the instantaneous distribution of current within the load. And the local reaction rate in the one dimensional site J (x) is related to the local metal ion concentration at the surface and to the overpotential by the kinetic expression associated with the metal deposition process.

Electrodeposition rate depends on the current density, which is usually held below the so-called limiting current density.

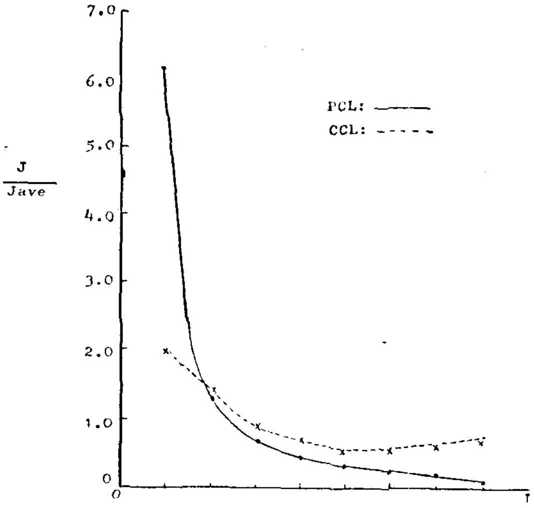
And the limiting current depends upon, at a typical electrolysis conditions, another type of mass transfer process occuring within the interior of this porous load, that means metalic ions entering into this porous region experience difficulty in reaching into the interior surface.

For the clearer explaning of the PCL two-dimensional analysis prefers to that of one-dimensional.

Here, we limit our scope to one-dimensional analysis.

To elucidate the metal deposit distribution from part to part,

For the test of the deposit distribution behavior of partially conductive load one dimensional model load was handled in almost analogous fashion as binding C-Dip units with nonconductive wire, looking like a prayer bead lace, and for that of the completely conductive load C-Dip metal frames itself used. The current distribution has been checked along the one-dimensional model metal by measuring the tin deposit thickness by assuming the electrochemical reaction follows after purely faradaic laws and the primary current distribution prevails. The current distribution along one-dimensional model in this report is presented normalized by weight deposited on this model, so that a uniform distribution corresponds to an abscissa value of unity.



X, Distance from free solution, Dimensionless

Fig. 2: Dependence of current distribution of CCL and PCL for the load depth (Barrel 8″×12″)

Metal distribution(or current) curves of PCL and CCL may be compared by changing electrolysis conditions; tin concentration, current density, barrel size and the rotation speed and the distance between cathode and anode. In this paper we are limited only to variance of applied current density and barrel RPM.

Fig. 2 shows that the curverture of PCL is sharper than the CCL case. It was observed that somewhat free movement of CCL C-Dip induced by the increase of barrel RPM, and therein produced fairly uniform metal distribution from part to part. For the systems considered, current is concentrated at the outer layer of the load(around x=0) in a distribution more ske wed toward the surface.

Both curves look like that of the behavior of high resistive metal electrode, but PCL case more worses. This can be explained as ohmic losses in PCL system being remarkable as well the potential in the electrode considerably varies with position.

As a consequence, the charge-transfer overpotential varies with position so that the electrode reaction may occur at different rates along the electrode surface, and mass transport restrictions is to rise up. Through this experiment (Fig. 3) we can understand the RPM will be one of modifying factors to control the uniformity of fairly distribution.

Higher RPMs reveals fairly even curverture rather than that of lower one.

Here we can find out the best RPM condition which is to give uniform curve.

Table 3: Current consumption rate(%) on the center rod in relation with the barrel rotating speed (Barrel 6″×9″)

R.P.M Current	0	6	13	20	28	36	44
15A	3.81	5.50	5.55	5.56	5.57	10.67	14.00
50A	1.13	1.70	1.71	2.00	2.46	3.27	—

Even though the parts connects at together with current supply 100% (like rotating disk) the rotation makes not remarkable contribution to the super uniform reaction distribution however encouraging results can be obtained in this PCL system through forcing the solution into the load deep. This seems that in this system lower metal concentration gradients establishes in And the increase of the rotating speed makes decrease the current efficiency decrease as described in Table 2.

At higher current distribution expressed in one-dimensional model showes quite different curves; center rod side (x=1) achieves thicker tin deposit compared to the out side of the load.

If following Fig. 3 shows curves of current distribution of PCL of C-Dip plated at several RPMs.

Such phenomenon seems due to the vigorous evolution of hydrogen gas in the outward side of the load, thus makes hinderance of tin depositing.

Approximately one third amount of the total applied current preferably consumed on the parts near to the cathode current contact rod

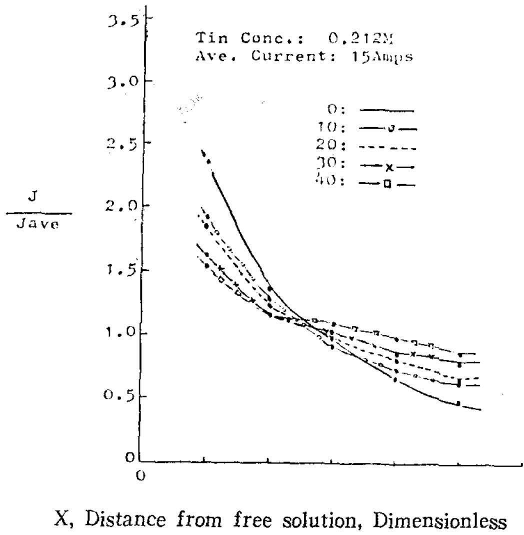


Fig. 3: Dependence of metal deposit distribution of PCL model upon various RPM. Tin plating time 6 min, Barrel 6″×9″

(x=1), and so cententrates average current density at around the center of this one-dimensional depth.

From theoretical approach (here omitted the derived procedures), it is possible for us to predict and to obtain somewhat higher values of polarization parameter by applying lower current density or by increasing solution conductivity throughaut the whole load.

In order to achieve higher yield of barrel plating effiiciency it comes sidered to be good to change tube-shaped center rod with the wave-shaped. As for the center rod of wave-shape is to render much more contact surface white providing increased.

Through this experiment we can predict new barrel design giving uniform current density as well as improved current efficiency.

Reference.

This paper is one portion of author's Master Degree Thesis of the Chemical Engineering, herein eliminated all those mathmatical formulas contained in the original paper, and also experimental procedures.