Investigations on the Characteristics of Pulse Plating on Printed Circuit Board

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ABSTRACT

A research is carried to evaluate the performance between the pulse plating and pulse reverse plating technique. In both the technique employed the composition of the bath is kept constant.Both the plating is done on a double sided Printed Circuit Board for the connection between the two layers. The metal used for plating is silver rather than the conventional copper. The evaluation of parameters such as hardness and current efficiency is carried out.

Keywords: Printed Circuit Board, Pulse plating, Pulse Reverse plating, silver, current efficiency

1. INTRODUCTION

Printed Circuit Boards (PCB) are the vital components of any electronic system. They are made of glass fiber with reinforced epoxy resin. Here efforts are taken to optimize the plating characteristics of a double sided Printed Circuit Board. Printed circuit boards have many constraints. This initial research leads into many areas of study in PCB design optimization and analysis. Main constraints of PCB is reduced area, increased component density, mixed signal components[14]. An effort to improve design technology and quality of PCB is carried out. Corrosion of electronic component especially PCB is a significant issue[7]. Copper is the material which is used widely for plating of PCB. Copper is corrosive when exposed to moisture. This characteristic is referred to as patina. When copper becomes corrosive it forms light blue powder.

$4Cu + 4OH - = 2Cu_2O + 2H_2O + 4e^-$-------(1)

The spacing between the components of PCB is less. Even if there is loss of picograms of the material in the conducting path of PCB it will lead to fault. Fault Tolerance of PCB is very less. The spacing between the components is of the order of 5 microns. Thus great care has to be taken to overcome this problem of corrosion.

2. RELATED WORK

Conventional method of plating for PCB is DC plating. Plating forms a very important step for double sided PCB [13].Here pulse plating technique is proposed. It consists of a plating bath and pulse rectifier equipment. In the plating bath, silver is used as anode and PCB board as cathode. Silver is a metal which has 7% higher conductivity than copper[12]. All metals are polycrystalline and they are built from any crystals.

When pulse plating of silver is done on PCB, it leads to leaving of ions from silver to the PCB board. It leads to the presence of an unoccupied state at anode. It is due to the electron migrating from anode to cathode.

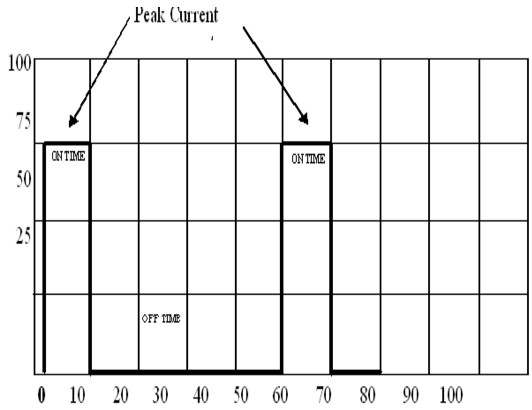

Fig 1 Pulse Current

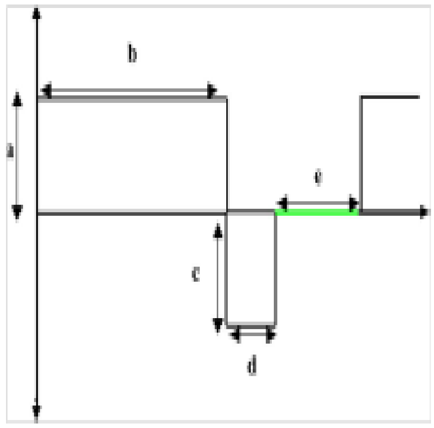

Fig 2 :Pulse reverse current

Iav=0.4ampere			**RPM = 50**		**Specimen area=0.41 mm^2**				
Ip=varies			**RTC = 180 sec**			**density of Silver = 10.49gm/cm3**			
Duty Cycle		**Pulse Frequency (Hz)**					**Theoretical weight (gms)**	**Theoretical Thickness (microns)**	**Peak Current density (A/dm^2)**
		10	**25**	**50**	**100**	**500**			
40%	Ton-Toff(ms)	40-60	16-24	8-12	4-6	0.8-1.2	0.0804	1.8716	3.9024
	Vav (volt)	0.22							
	I_P (ampere)	1.6							
	WED (grams)	0.03	0.02	0.02	0.02	0.014			
	Exp. Th. (µm)	0.60	0.58	0.43	0.42	0.296			
	Efficiency %	39.8	72.7	32.3	27.3	17.4			
60%	Ton-Toff(ms)	60-40	24-16	12-8	6-4	1.2-0.8	0.0804	1.8716	1.4634
	Vav (volt)	0.29							
	I_P (ampere)	0.6							
	WED (grams)	0.042	0.032	0.023	0.019	0.012			
	Exp. Th. (µm)	0.693	0.601	0.451	0.332	0.252			
	Efficiency %	50	39.8	28.6	23.6	14.9			
80%	Ton-Toff(ms)	80-20	32-8	16-4	2-8	1.6-0.4	0.0804	1.8716	1.219
	Vav (volt)	0.32							
	I_P (ampere))	0.5							
	WED (grams)	0.078	0.073	0.052	0.041	0.010			
	Exp. Th. (µm)	2.006	1.902	0.741	0.691	0.241			
	Efficiency %	97.2	90.7	64.6	50.9	12.4			

Table 1: Various calculations in pulse reverse plating

Definition	**Mathematical expressions**
Frequeny	f = 1/(b+d+e)
Average current intensity	I_d=(a*b+c*d)/(b+d+e)
Current ratio	R=c/a
Off time	T_{off}=e
Positive duty cycle	ζ^+=b/(b+d+e)
Negative duty cycle	ζ^-=d/(b+d+e)
On duty cycle	ζ^{on}=(b+d)/(b+d+e)

In the above fig1 , duty cycle is a very important parameter[1].It contains two parameters. They are ON and OFF time. Duty cycle is given by ON time divided by total time(ON time + OFF time)[4]. In order to attain extensive duty cycle range square pulses are used [11] .

Fig 2 refers to Pulse reverse current waveform with the five parameters highlighted
(a) cathodic current intensity amplitude,
(b) cathodic pulse duration on time,
(c) anodic current intensity amplitude,
(d) anodic pulse duration on time, and
(e) off-time of the pulse

There are 3 possible periods.

1 Forward ON+OFF

2 Reverse ON+OFF

3 Forward+Reverse

The most important part of calculation is that at any time in the opposite direction is same as OFF Time to the direction being calculated and that all of the ON time must be considered for the direction being calculated and not the ON time of one ON+OFF period [13].

When the first pulse is used the concentration of the silver ion falls, its value increases during the off-time during the second pulse the process repeats. The movement of silver ions in bath is due to the hydrogen evolution and also due to the raise of Ph value at the surface [8].It is also observed that metal deposition is not dependent on pulse lengths.

Table2.

From Table 2 The Experimental Data Obtained for Various Pulse Duty Cycles of 20% to 80%, at Frequencies 10 Hz, 25 Hz, 50Hz,100 Hz and 500 Hz with a Constant Average Current Density0.975amps/dm^2,where Iav =0.4 amps (Iav = average current, RPM = Rotation per minute, I_p = peak current , RTC = Real time cycle, Ton-ON Time, Ton-OFF Time, WED= Weight Electrodeposited, Exp.Th.-Experimental Thickness) The above values are obtained from pulse plating set up.It is observed that with higher duty cycle higher efficiency is obtained.As the duty cycle increases the grain size decreases.

Table 3: Tabulation for Pulse Reverse plating The Various Experimental Data Given to the Rectifier for Pulse Reverse Plating of Double Sided Printed Circuit Board

DoE	Reverse duration (ms)	Reverse ON time(ms)	Reverse OFF time (ms)	Forward duration time (ms)	Forward ON time (ms)	Forward OFF Time (ms)
1	-20	15	5	30	20	10
2	-30	20	10	20	15	5
3	-20	5	15	30	20	10
4	-20	5	15	30	10	20
5	-30	25	5	40	30	10
6	-40	30	10	30	25	5
7	-30	5	25	40	10	30
8	-30	5	25	40	30	10
9	-40	30	10	30	20	10
10	-40	30	10	20	30	10
11	-40	20	20	30	15	5
12	-40	15	5	30	5	15
13	-40	10	30	20	15	5
14	-40	10	30	20	5	15
15	-30	10	20	20	15	5
16	-20	10	10	30	15	5
17	-50	40	10	40	30	10
18	-40	30	10	50	40	10
19	-50	10	40	40	30	10
20	-50	10	10	40	10	20
21	-50	20	30	40	30	10
22	-50	30	20	40	20	10

Ireverse = 1amps and Vreverse= 10 volts , (DoE = Design of Experiment)

Table 3 shows the various experimental data given to the pulse reverse plating setup. The values are designed in such a way that it yields high current efficiency and hardness to the plated printed circuit board. The difference between pulse plating and pulse reverse plating is that with pulse plating there will be only one ON +OFF cycle but in reverse pulse plating technique there will be several ON + OFF cycles. If the ON time is in opposite direction then it is equal to OFF time. While calculating not only one ON time is taken for calculation but all ON time of the whole period is taken for calculation .From Table 3 it is observed that No forward ON time is in negative direction

Table 4 The Experimental Data Obtained for Various Pulse DutyCycles of 10% to 100%

Ireverse = 1amps and Vreverse= 10 volts ,(DoE = Design of Experiment) RTC =600sec .

DoE	Forward duty Cycle (fDC) in %	Effective forward duty cycle (efDC) in %	Reverse duty cycle (rDC) in %	Effective reverse duty cycle (erDC) in %	Effective Plating Current
1	66.7	40	75	30	-0.3
2	75	30	66	40	-0.4
3	66.7	40	25	10	-0.1
4	66.7	40	25	10	-0.1
5	75	50	100	33.3	-0.3
6	83.3	35.7	75	42.9	-0.4
7	25	14.3	16.7	7.1	-0.1
8	75	42.9	16.7	7.1	-0.1
9	66.7	28.6	75	42.9	-0.4
10	100	33.3	75	50	-0.5
11	83.3	35.7	50	28.6	-0.3
12	33.3	14.3	75	42.9	-0.4
13	75	25	25	16.7	-0.2
14	25	8.3	25	16.7	-0.2
15	75	30	33.3	20	-0.2
16	83.3	50	50	20	-0.2
17	75	33.3	80	44.4	-0.4
18	80	44.4	75	33.3	-0.3
19	75	33.3	20	11.1	-0.1
20	50	22.2	60	33.3	-0.3
21	75	33.3	40	22.2	-0.2
22	75	33.3	60	33.3	-0.3

From Table 4 for the DOE the respective fDC and efDC is calculated. The fDC is the duty cycle of the settings during the forward time of the waveform. The efDC is the duty cycle of the forward time relative to the overall waveform .rDC is the reverse duty cycle of the settings during the reverse time of the waveform. erDC is the effective duty cycle of the reverse time relative to the overallwaveform.

Since there are continuous forward and reverse pulses in Pulse reverse plating technique, it will lead to coarse deposits at the first cycle ,then the reverse current will dissolve the excess of silver deposited , the following forward cycle will plate the silver without any dog boned deposits. Thus reverse cycle leads to better efficiency when compared to pulse plating . But there is a disadvantage that the RTC (Real Time Cycle) maintained is at higher rate when pulse reverse plating is carried .

Table 5 The Experimental Values Namely Frequency, Average Current Intensity, Positive Duty Cycle, Negative Duty Cycle and ON Duty Cycle RTC =600 sec

DoE	Frequency (Hertz)	Average current intensity (mA)	Current Ratio	Positive duty cycle (%)	Negative duty cycle (%)	On duty cycle (%)
1	25	22.5	0.667	40	37.5	87.5
2	22	20	1.5	33	44.4	77.7
3	25	17.5	0.667	50	12.5	62.5
4	33	13.3	0.667	33	16.6	50
5	16.6	32.5	0.75	50	41.6	91.7
6	15.4	30	1.33	38.5	46.2	84.6
7	25	13.75	0.75	25	12.5	37.5
8	16	22.5	0.75	50	8.3	58.33
9	16	30	1.33	33	50	83.3
10	14.3	25.7	2	43	42.8	85.7
11	18.2	22.7	1.33	27.3	36.36	63.6
12	40	30	1.33	20	60	80
13	18.2	12.7	2	27.3	18.2	27.3
14	22	11.1	2	11.1	22.2	33.3
15	22	13.3	1.5	33.3	22.2	55.5
16	28.6	18.57	0.667	42.8	28.6	71.4
17	12.5	40	1.25	37.5	50	87.5
18	12.5	40	0.8	50	37.5	87.5
19	12.5	21.25	1.25	37.5	12.5	50
20	33	30	1.25	33.3	33	66.7
21	12.5	27.5	1.25	37.5	25	66.7
22	14.3	32.85	1.25	28.6	42.9	71.4

Table 6 The Experimental Data Obtained after Pulse Reverse Plating Namely Current Efficiency and Hardness

DoE	Average current intensity (mA)	Average current Density mA/ mm^2	Theoretical weight (grams)	Experimental Weight (grams)	Current efficiency (%)	Hardness (VHN)
1	22.5	54.87805	0.0150	0.0146	97.2	76.4
2	20	48.78049	0.0134	0.0123	92.3	73.2
3	17.5	42.68293	0.0117	0.0103	88.4	76.2
4	13.3	32.43902	0.0089	0.0050	56.2	82.2
5	32.5	79.26829	0.0218	0.01813	83.2	70.4
6	30	73.17073	0.0201	0.0162	80.6	68.2
7	13.75	33.53659	0.0092	0.00547	59.4	76.1
8	22.5	54.87805	0.0150	0.0146	97.2	70.8
9	30	73.17073	0.0201	0.0162	80.7	68.1
10	25.7	62.68293	0.0172	0.01625	94.3	68.1
11	22.7	55.36585	0.0152	0.01496	98.3	71.2
12	30	73.17073	0.0201	0.0162	80.6	87.3
13	12.7	30.97561	0.0085	0.00402	47.3	70.1
14	11.1	27.07317	0.00744	Poor deposit		
15	13.3	32.43902	0.00892	0.00501	56.2	73.1
16	18.57	45.29268	0.01245	0.01128	90.6	78.2
17	40	97.56098	0.02683	Burnt deposit		
18	40	97.56098	0.02683	Burnt deposit		
19	21.25	51.82927	0.01425	0.01347	94.5	65.3
20	30	73.17073	0.02012	0.0162	80.7	82.2
21	27.5	67.07317	0.01844	0.01663	90.2	65.3
22	32.85	80.12195	0.02203	0.01833	83.2	66.3

3. RESULTS AND DISCUSSION

From the tabulations obtained for various average current density it is observed that the highest current efficiency is found for constant average current density 55.36585 .DOE 11 has Reverse duration as 40seconds, Reverse ON time as 20seconds reverse OFF time as 20 seconds, Forward duration time as 30 seconds ,Forward ON time as 15 seconds and Forward OFF time as 5 seconds. The maximum current efficiency obtained is 98.3.The maximum hardness obtained is at DOE12 and its value is 87.3 but its current efficiency is 80.3. So DOE11 is considered as optimal fo plating .

4. CONCLUSION

Silver on pulse plating for double sided PCB with necessary thickness inside hole provides long lasting and reliable corrosion preventive agent.The area where this silver plating does not work effectively and form corrosion is when it is exposed to the atmosphere of hydrogen sulphide[10]. Otherwise, silver that too with pulse plating is the best form for double sided printed circuit boards particularly.Here, silver is used for plating instead of the conventional copper.When copper is used it leads to corrosion , whereas silver is highly corrosion resistant. Corrosion can impair the wire's fatigue life and electrical conductivity.

Reasons for choosing silver instead of conventional copper are Exceptional Electrical Conductivity nearly 7% higher conductivity than copper.It has a good resistance to high temperature.Suitable for RF applications .Solder ability and crimpability is high. Use of Silver leads to better hardness and current efficiency. It is reliable for space craft applications

5. ACKNOWLEDGEMENTS

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