

"IMPROVED SOLDER PLATING PROCESS AND SEMICONDUCTOR
PRODUCT"

5 The present invention relates generally to
the packaging of integrated circuits and other
semiconductor products in synthetic plastic packages
from which exposed metal leads protrude. More
particularly, the invention relates to an improved
method of coating the leads to provide protection and
10 to facilitate soldering the leads to a printed
circuit board.

15 In packaging semiconductor devices, the
integrated circuit (usually referred to as a chip or
die) is connected to a plurality of metal leads,
typically by either wire bonding techniques or
automated tape bonding. After such connection, the
die is encapsulated in either a synthetic plastic or
a ceramic which protects the die and defines what
20 will be referred to hereinafter as the semiconductor
package. The present invention relates particularly
to such semiconductor packages wherein the
encapsulant is a plastic.

25 The metal leads, which are typically of
copper or a copper alloy project from the
semiconductor package and may ultimately be connected
to other circuitry by conventional soldering
techniques. Copper, however, cannot be directly
30 soldered and it is preferable to coat the leads with
a thin layer of tin or a tin/lead alloy to facilitate
soldering.

35 Heretofore, two primary methods for coating
the metal leads have been employed, both of which
methods are applied to the semiconductor package

after encapsulation is complete. The first method relies on dipping the semiconductor package in molten tin or tin/lead alloy for a brief period, typically from 1 to 10 seconds. While this method is reasonably effective, the high temperature of the molten metal, typically from about 230°C to 260°C, places severe thermal stress on the package and can cause gaps around the leads to develop in the plastic package. Moreover, the solder coat applied to the leads often has a non-uniform thickness which can inhibit subsequent manipulation of the device, particularly automatic insertion onto printed circuit boards.

The other method for coating a layer of solder onto the metal leads relies on electroplating in a suitable plating bath. To accomplish such electroplating, the packages are first cleaned, typically with a strong mineral acid such as hydrochloric acid, sulphuric acid, nitric acid, phosphoric acid, and the like. The plating electrolytes utilized typically consisted of corrosive acids, and tin/lead salts. For example, when coating pure tin, sulphuric acid based electrolytes were used. For coating tin/lead alloys, fluoboric acid based electrolytes were used. Alternatively, alkane/alkanol sulphonic acid based electrolytes were used.

When solder is electroplated on plastic semiconductor packages, severe corrosion of the metallization (e.g. aluminium) on the semiconductor die can result if the package has small gaps between the plastic encapsulation material and the metal leads. Such gaps allow the corrosive cleaning solution and plating electrolyte to penetrate the

plastic body of the semiconductor package. Once the corrosive materials have entered, subsequent rinsing and cleaning of the packages are often not effective to remove it. Even very small amounts of corrosive material left on the metallization for long periods of time can result in corrosion of the metallization and render the package liable to failure.

It would therefore be desirable to provide methods for solder plating the metal leads of plastic semiconductor device packages in such a manner that corrosion of the metallization layers is largely avoided.

U.S. Patent No. 4,163,700 discloses an electroplating bath for tin or tin alloys which includes tin salts, such as tin citrate, dissolved in a citric acid solution. the plating bath further includes a hydroxycarboxylic acid (other than citric acid or citrate) and/or a dibasic carboxylic acid. LeaRonal, Inc., Freeport, New York, sell an electroplating system for plating tin and/or tin alloys on various metals. The system is sold under the trade name "Solder On SG" and comprises tin and lead salts in a sulphonic acid based system. A sequestering agent (Solder On SG Make-up) of unidentified composition is included in the electroplating system. LeaRonal, Inc., recommend that their system be used on ceramic semiconductor packages, where the metal leads are cleaned with a strong mineral acid, such as sulphuric acid, prior to electroplating.

The present invention provides a method for solder plating metal leads on plastic semiconductor packages, which method employs non-corrosive cleaning and electroplating solutions to avoid damage to the metal leads and encapsulated semiconductor die even when small gaps exist in the plastic package. The method comprises two steps, where the first step is the cleaning of the metal leads the semiconductor package using an organic acid selected from carboxylic acids and hydroxycarboxylic acids. The second step is electroplating the leads with solder in a non-corrosive plating solution.

In the preferred embodiment, the organic acid in the cleaning solution is either citric acid, oxalic acid, or a combination of either of these acids with another organic acid, and the cleaning is performed at an elevated temperature. The electroplating solution includes an alkanol/alkane tin salt, or tin salt and an alkanol/alkane lead salt, in a non-corrosive plating bath, where the relative amounts of tin and lead depend on the desired composition of the solder plate. The metal salts are present in either sulphonic acid or citric acid. The sulphonic acid plating bath includes a tin alkylsulphonic salt and/or a lead alkylsulphonic salt, and a sequestering agent to inhibit attack of the fluoboric acid on the metallization. In the citric acid based system, tin citrate and/or lead citrate are dissolved in the citric acid. Plating may be carried out in apparatus of known form to apply the desired thickness of the solder to the lead frame.

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The method of the present invention is useful for solder plating metal leads on plastic semiconductor packages, such as the standard dual-in-line packages which are used throughout the microelectronics industry. Semiconductor dies are mounted on lead frames and encapsulated in plastic to protect the semiconductor die and facilitate mounting. The lead frames are usually composed of copper, a copper alloy, or a nickel-iron alloy and include a plurality of individual leads which extend outward from the plastic package. The leads are usually soldered to printed circuit boards. In order to protect the leads and enable them to be soldered to printed circuit boards or other devices, it is desirable to coat the leads with a layer of tin or tin/lead alloy.

The cleaning solution comprises a mild organic acid preferably selected from carboxylic acids and hydroxycarboxylic acids. By employing the acid cleaning solution at a mildly elevated temperature, the leads will be cleaned, but any residual acid which penetrates the package through small gaps or interstices in the package will not corrode the aluminium metallization on the semiconductor die. The problem with prior art cleaning solutions, which typically had been strong mineral acids, such as sulphuric acid, nitric acid, and the like, was that any acid which penetrated the package could not be washed away. Thus, these acids remained in the package for extended periods and were likely to cause great damage.

Carboxylic acids useful in the cleaning solution of the present invention include oxalic acid, malonic acid, succinic acid, glutaric acid, and the like. Suitable hydroxycarboxylic acids include citric acid, tartaric acid, malic acid, lactic acid,

ascorbic acid, and the like. These acids will typically be employed at a concentration in the range from about 10 to 200 grams/litre more typically in the range from about 100 to 150 grams/litre.

5 Exposure will be at a temperature in the range from 25 to 100°C, and for a time in the range from 1 to 20 minutes.

10 Care must be taken with both the carboxylic acid cleaning solutions and the hydroxycarboxylic acid cleaning solutions to make sure that the solutions are fresh and to change the solutions when they become laden with heavy metals, such as copper. Copper and other metals will redeposit on the leads and interfere with the plating of the
15 solder.

The electroplating solution for depositing the solder layer, either tin or a tin/lead alloy, on the aluminium leads is also non-corrosive. Two electroplating systems have been found suitable for
20 the present invention. The first of these systems is a sulphonic acid based electrolyte while the second system is a citric acid based electrolyte. A sequestering agent is utilized with the sulphonic acid based electrolyte to further inhibit corrosion
25 of the aluminium surface.

The sulphonic acid plating system typically utilizes a tin alkane/alkanol sulphonate salt and/or a lead alkane/alkanol sulphonate salt, where an alkane or alkanol radical has from 1 to 6 carbon
30 atoms, more usually from 1 to 3 carbon atoms. The concentrations of these salts will vary depending on the desired ratio of tin to lead and the solder plate, typically being in the range from 5 to 100 grams/litre more typically being in the range from 5
35 to 100 grams/litre. For achieving a tin/lead solder having a ratio of tin:lead of 90:10, a suitable

plating solution would have approximately 25 grams/litre tin alkane sulphonate and 5 grams/litre (excess) lead alkane sulphonate. Conveniently, tin methane sulphonate and lead methane sulphonate may be utilized as the salts. The concentration of the sulphonic acid is typically in the range from 5 to 30% by volume, more typically being in the range from 10 to 20% by volume.

The sulphonic acid based electrolyte will include a sequestering agent selected to inhibit acid attack by the electrolyte on the aluminium and other components internal to the semiconductor package. Suitable sequestering agents include sodium metasilicate and Solder On SG Make-up available from LeaRonai, Inc., as part of their Solder On SG system. These sequestering agents are typically utilized at the concentration in the range from 1 to 50 grams/litre more typically in the range from 5 to 30 grams/litre.

The citric acid plating solution typically includes a tin sulphonate salt and/or a lead sulphonate salt, at concentrations selected to yield the desired tin/lead ratio in the solder plate. Typically, the tin sulphate salt will be present at a concentration in the range from about 5 to 100 grams/litre while the lead sulphate will be present in the range from about 1 to 50 grams/litre. Concentrations suitable for producing a 90% tin alloy would be 25 grams/litre tin sulphate and 5 grams/litre lead sulphate. The concentration of the citric acid is not critical, typically being in the range from about 10% to 100%. By adjusting the pH of the citric acid electrolyte to a value in the range from about 6 to 7, typically with Na_4OH , it has been found that the electrolyte will be substantially non-corrosive to the aluminium

metallization.

The plating method of the present invention may be performed in conventional electroplating equipment. The plating tank should be made of an acid resistant material such as an acid-resistant polymer, e.g., polypropylene, polyvinylchloride, or the like. Plating racks are provided internal to the plating tank, and a suitable power supply is utilized to provide the necessary plating current. The anode is typically a tin/lead alloy having a tin/lead ratio which matches the desired composition of the solder plate. The cathode is connected to the plating rack, and the plating power supply is run at a low voltage, typically from 1 to 20 volts, usually about 3 volts, for a time sufficient to supply the desired thickness of solder plate. The thickness will usually be in the range from about 0.3 to 2 mils. The amount of current required will depend on the number of packages being plated and on the amount of time allowed for the plating process. Generally, a higher current will correspond to a shorter plating time.

The following examples are offered by way of illustration, not by way of limitation.

EXPERIMENTAL

1. Corrosive Effect of Plating Baths on Metallization Layers on Silicon Dies.

Silicon dies having exposed aluminium metallization layers were immersed in the plating solutions listed in Table 1 and microscopically examined for corrosion after 5 minutes, 24 hours, 55 hours, 80 hours, and 100 hours. The sequestering agent employed was either "Solder On SG Make-up" sequestering agent from LeaRonol, Inc., Freeport, New York, or sodium metasilicate.

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Table 1

Sample No.	Plating Solution	Sequestering Agent	Extent of Corrosion				
			5 Min.	24hr.	55hr.	80hr.	100hr.
1	Stannous Sulfonate; 10% H ₂ SO ₄	None	100%	-	-	-	-
2	Stannous Fluoborate (15g/l); Lead Fluoborate (10g/l); 40% Fluoboric acid	None	100%	-	-	-	-
3	Stannous Sulfonate; (25g/l); Lead Sulfonate (5g/l); Citric Acid	None	0	0	0	0	0
4	Stannous alkane sulfonate (25g/l); Lead alkane sul- fonate (5g/l); 20% Methane sulfonic acid	None	0	15%	100%	100%	100%
5	Same as Sample 4	5% Make-up	0	0	0	0	15%
6	Same as Sample 4	20% Make-up	0	0	0	0	0
7	Same as Sample 4	1 g/l sodium metasilicate	0	-	-	-	-

2. Corrosion Inhibition Effect of Sequestering Agent

Silicon dies having exposed aluminum metallization layers were immersed in the plating solutions given in Table 2. The corrosion occurring after 24 hours, 55 hours, and 103 hours was visually assessed under a microscope, and the results are noted.

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Table 2

Sample No.	Tin sulfonate			Lead sulfonate		Wetting agent (Z vol.)	Sequestering Agent ^a (Z vol.)	DI Water (Z vol.)	Extent of Corrosion		
	salt (g/l)	salt (g/l)	salt (g/l)	salt (g/l)	salt (g/l)				7Z	100Z	100Z
1	30	0	0	0	0	0	0	75	7Z	100Z	100Z
2	0	9	"	"	"	"	"	98	0	100Z	100Z
3	"	0	"	20	"	"	"	80	0	0	0
4	"	"	"	0	"	20	"	"	"	"	"
5	24	9	"	20	"	"	"	38	"	"	"
6	30	7.2	"	"	"	"	"	33.5	"	"	"
7	27.5	8.6	0	0	0	0	0	75	7Z	100Z	100Z
8	"	"	5	5	"	"	"	70	0	0	7Z
9	"	"	10	10	"	"	"	65	0	0	0
10	"	"	20	20	"	"	"	"	0	0	0
11	"	"	24	24	"	"	"	55	0	0	0
12	"	"	20	20	"	5	5	50	0	0	0
13	"	"	20	20	"	20	20	35	0	0	0

^a Make-up



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CLAIMS

1. A method for solder plating metal leads on a plastic semiconductor package, said method comprising: exposing the plastic semiconductor package to a carboxylic or hydroxycarboxylic acid to remove metal oxide from the leads; and electroplating tin or a tin/lead alloy onto the metal leads in a non-corrosive electrolyte wherein tin salts or tin and lead salts are present in sulphonic acid or nitric acid.
2. A method according to claim 1 in which the carboxylic acid comprises one or more of oxalic acid, malonic acid, succinic acid, and glutaric acid.
3. A method according to claim 2 in which the hydroxycarboxylic acid comprises one or more of citric acid, ascorbic acid, malic acid, and lactic acid.
4. A method according to any foregoing claim, in which the carboxylic or hydroxycarboxylic acid is at an elevated temperature.
5. A method according to any foregoing claim, in which the electrolyte is based on sulphonic acid and includes a sequestering agent.
6. A method according to any of claims 1 to 4 in which the electrolyte is based on citric acid and has a pH in the range from 6 to 7.



7. A method according to any of claims 1 to 4 in which the plating bath includes tin alkane sulphonate salt or a tin alkane sulphonate salt and a lead alkane sulphonate salt in a sulphonic acid electrolyte.

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8. A method according to any of claims 1 to 4 in which the electrolyte includes a tin citrate salt or a tin citrate salt and lead citrate salt in a citric acid electrolyte.

10 9. Semiconductor packages produced according to the method of any foregoing claim.
