REVIEW OF SELECTIVE PLATING PROCESS FOR LEAD FRAME MANUFACTURING

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Abstract: Electroplating play an important roles in semiconductor manufacturing industries. A layer of silver or gold was selectively plated on the surface of lead frame by using electroplating technology. The purpose of depositing a layer of gold or silver on the surface of lead frame is to improve the bondability during die attach and wire bonding process. Since the bonding process does not involve all surfaces of the lead frame, selective plating is essential in order to eliminate the waste of precious metals such as gold and silver. Basically, to selectively plate precious metal on lead frame, there are several methods can be used and these methods can be grouped into two categories – masking and spot/jet plating. In this paper, a review of the selective plating processes in lead frame manufacturing industries will be presented. The detail of masking and also spot plating process will be explained to help reader understand these processes. The advantages and limitation of each process also will be discussed and the comparison will be made among these processes.

INTRODUCTION

Electrochemical technology entered the electronics industry some 50 years ago as a manufacturing process for low-end printed-circuit boards. Today, electrochemical technology is employed widely for the processing of advanced microelectronic components, including high end packages and interconnects, thin film magnetic heads and micro-electro-mechanical systems (Landolt & Datta, 1999). Electrochemical microfabrication technology is expected to play an increasingly important role in the electronics and microsystems industry because of its cost effectiveness and achievable high precision. In addition, electrochemical processes are attractive from an environmental point of view because material deposition or removal is highly selective thus minimizing waste (Landolt & Datta, 1999). With the miniaturization of electronic devices, the connection reliability between integrated circuit (IC) and the external circuits has become important. Electroplating and electroless plating have been applied for the metallization of electronic components. Recently, advanced plating technology is strongly in demanded for the manufacturing of electronic components, because many devices are becoming finer and more complicated (Honma, 2001).

The use of electrochemical technologies is increasing in the semiconductor industry. In packaging, electrochemical materials are used to address power delivery and dissipation, including electroless deposition and electroplating for substrates, electroplating bumps to connect die to substrate, plating for die sacking and 3 dimensional interconnect (Dubin, 2003). In chip metallization, electrochemical materials are used to reduce Resistor-Capacitor (RC) delay and increase electromigrration resistance, including electroplated interconnects with low resistivity and higher electromigration resistance than aluminium (Al) interconnects, and electroless plating for cladding, barrier and seed layer applications. In transistor, electrochemical materials are used to form silicon on isolator (SOI) by employing porous silicon to reduce transistor leakage. Electrochemical processing offers low cost, excellent scalability to smaller feature sizes and the capability of preferential, selective growth to form patterns (Dubin, 2003).

The electrodeposition of semiconductor has been investigated in detail and demonstrated by a large number of workers over many years (Schlesinger & Paunovic, 2000). This effort is primarily motivated by the fact that electrodeposition is a relatively simple and inexpensive deposition technology that may be scaled up easily. In general, the films deposited by this method do not possess the crystalline perfection or low levels of electrically active impurities of single crystal epitaxial films deposited by techniques such as molecular beam epitaxy or chemical vapor deposition. Nonetheless, in applications where large area of semiconductors are required, such as photovoltaic power generation or corrosion protection as opposed to integrated circuit fabrication, the low cost and comparatively low material demands make this deposition technology attractive in terms of ultimate commercialization (Schlesinger & Paunovic, 2000).

In lead frame manufacturing industry, a layer of precious metal such as gold or silver was selectively plated on surface of lead frame by using electroplating technology (Bestel et. al, 1977). The purpose of deposits a layer of silver or gold on the surface of lead frame is to enhance the bondability during die attach and wire bonding process. Beside that, the precious metal also use as a protection layer to avoid oxidation during wire bonding process. Since the bonding process not involve all surface of the lead frame, selective plating is essential in order to eliminate the waste of precious metals. Basically, to selectively plate precious metal on lead frame, there are several methods can be use. In this paper, a review of the selective plating methods will be presented. The detail of process review for each method will be explained in the following section. To ensure reader understand the selective plating process, the detail explanation regarding process advantages and limitation including the comparison for each method will also be presented.

EXISTING SELECTIVE PLATING METHODS

An apparatus for continuously depositing a metal with desired pattern on a strip of electrically conductive material (lead frame) has been discovered by Donaldson (1972) in US patent 3644181. This apparatus comprising a motor for continuously advancing a strip of electrically conductive material, at least one electroplating station that comprises a housing of an electrically insulative material (rubber), one face of the housing being in contact with the strip of material, an anode recessed in the housing, a channel connecting the anode and the strip with the width of the channel being approximately equal to the width of the desired pattern, and an inlet and outlet for the electroplating solution at opposites ends of the channel. A pump will continuously supply the electrolyte to the inlet of channel from a collecting tank with high velocity. The electrolyte will flow from inlet channel to the outlet channel and impinge on the surface of the strip before flow to the collecting tank. A strip of conductive material will be connected to the negative terminal of the power supply. When current is supply to the system, electroplating will take place on the area that has the flow of electrolyte. In this method, production time can be reduced by maintaining a relatively high current density at the cathode in relationship to the speed of travel of the strip and by maintaining a relatively high velocity of the electroplating solutions passing the cathode. Thus, the production cost is reduced.

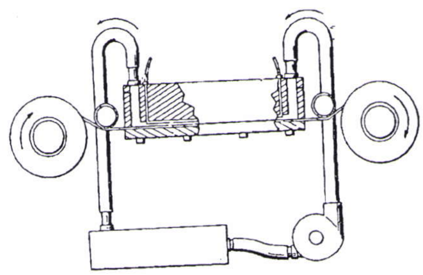

Figure 1: Apparatus for continuously depositing a metal (US Patent 3644181, 1972)

A method of selective plating of lead frame sheets has been described by Uchytill et. al (1972) in US patent 3663376. In this method, photosensitive and photohardenable material was used as a masking material to cover the area that is not needed to be plated in both side of lead frame. Firstly, one side of lead frame surface will be coated with photosensitive facing. After that, photohardenable material is applied to the plurality and narrow passages of lead frame. Finally, the second photosensitive facing is applied on the others side of lead frame. The coated lead frame will go through the exposure chamber to determine the desired plating pattern. In the exposure chamber, both side of lead frame will be exposed to the light with wave length 3280 ~ 3720 Angstroms. The portion of sheet that needs to be plated will be masked and the photosensitive facing and photohardenable only will harden on the area that expose to radiant energy. The unexposed photosensitive (area be masked) will be removed by using chemical developing solution, thus form the desired plating pattern on lead frame. The lead frame with desired pattern will be dipped into the electroplating solution and plating will take place when current is supply to the system. After complete the plating step, harden photosensitive and photohardenable material will be removed from lead frame by using potassium hydroxide solution at a temperature of 220°F. This method is highly effective in accurately and precisely masking all those portions of lead frame which do not require plating including its narrow passageways. Thus, eliminates additional cleanup steps to remove plating materials from undesired parts.

The US patent 3810829 by Oliver and Flecther (1974) has explained a scanning nozzle plating system. In this system, substrate to be plated is supported on a stationary platform. A nozzle assembly with a small nozzle is supplied with a plating solution under high pressure, so that a constant flow stream of solution is directed to substrate. The nozzle assembly is moved relative to the substrate at a selected rate and movement pattern. A potential difference is provided between the substrate and the solution in the assembly. The voltage amplitude is modulated so that only when the amplitude is above minimum known value plating takes place. A controller is supplied with the scan control signals and the pattern defining signals. The scan control signals is used to control the relative motion between the nozzle assembly and the substrate, while the pattern defining signals is used to modulate the amplitude of a voltage with which the stream is charged. As a result, a pattern corresponding to the scanned original pattern is plated on the substrate. The plating thickness is determined by the stream current amplitude and the nozzle assembly movement rate. During the constant flow stream of the electrolyte strikes the substrate, some droplets are separated from the stream. These droplets contain only surface charges which are not sufficient to produce plating. These droplets tend to clean the substrate surface by washing it as they are driven off, thereby insuring the cleanliness of the surface on which plating is to take place. A stream of air is used to remove the formed droplets from the plated surface. This method not only eliminates the masking process, but also can easily performed plating with any pattern by changing the scan control and pattern defining signal.

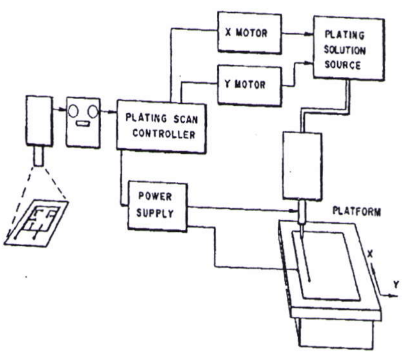

Figure 2: Scanning nozzle plating system (US Patent 3810829, 1974)

In the US patent 3860499 by Graham (1975), an apparatus for selectively electroplating a strip (lead frame) has been described. This method consist a positioning devices to adjust the strip and ensure the strip in proper align position before entering the plating station. Mean while the plating station consist of an open-top container for supplying the electrolyte and determine the plating pattern (by rubber mask which attached to the open-top container), and the adapter as a seating device to seal the open-top container and the strip. The strip will connect to the negative terminal of the power supply and the positive terminal will be connected to the conductor inside the open-top container. When the open-top container is seal with the strip by the seating device, the pump will force the electrolyte from the reservoir to the open-top container. A valve with timer is used to control the level of electrolyte on the open-top container. Once the level of electrolyte in the open-top container rises and passes through the rubber mask of the container and engages the pre-selected area, the plating will take place. In this apparatus, fluid actuated cylinder is used to control the movement for the strip horizontally and the movement of the seating device vertically. This method can selectively plate the strip continuously but the limitation of this method is it only can plate one type of pattern at one time. When the others plating pattern is required, the mask on the open-top container must be changed. The setup time is long for changing the mask.

An apparatus for selectively plating lead frames has been invented by Pantiga and Allen (1977) in US patent 4033844. In this patent, a method for selectively plating the lead frame strip is described. This method comprises three plating station. Each station is used to plating the different part of the lead frame with different pre-determined area. In the first station, a rubber mask with the pattern that tips and the pad of lead frame uncover is used. Thus, in this station, the tips and pad will be plated with gold of copper strike. In the second station, a rubber mask is provided to masking the tips and plating pad only with second pre-determined metallic coating (gold). In the third station, a rubber mask is provided to masking the pad and plating the tips with third pre-determined metallic coating (silver). The stations are arranged in series fashion so that the continuous strip or series of lead frames may be sequenced in a step through the stations such that the plating performed in each station is carried out simultaneously. The plating station comprises a container with rubber mask and anode, a supplying pipe to supply the electrolyte from reservoir to the container, adapter to seal the container with the strip (using rubber band with pin to seal from both side of adapter). In this method, the container is seal with adapter first. After that, the electrolyte is supplied to the container by a pipe from reservoir. When the electrolyte in the container rise through the rubber mask and engages the pre-selected area and the power is supply, plating will take place. According to the inventor, this method can performed plating quickly and efficiently.

A method for electroplating an area of a surface has been explained by Bestel et. al (1977) in US patent 4033833. In this method, the substrate is cathodically charged by connecting the substrate to negative terminal of power supply. While the anode comprises an electrolyte inlet and dielectric outlet portion and connected to the positive terminal of power supply. The electrolyte portion is connected to the pump which continuously supply electrolyte to anode from the electrolyte collecting tank. Mean while, the dielectric outlet channel having a certain dimension, orientation and shape, as well as certain dielectric to cathode distance which determine by plating parameters such as electrolyte flow rate and current density desired. In this method, the electrolyte is continuously supply from the collecting tank to anode by a pump. The continuous flowing stream of electrolyte will go through channel outlet and impinges on the surface of substrate. When current supply is efficient, plating will take place. The geometry of the channel outlet will determine the plating pattern on the surface of substrate. This method also eliminates the masking process and desired pattern can be easily changed by changing the geometry of the channel outlet.

In the US patent 4410562 by Yuhei and Shiro (1983), a method for forming a cured resin coating having a desired pattern on the surface of a substrate has been mentioned. This method comprises a first step of applying a coating of an ultraviolet light curable resin to the surface of substrate; a second step of pre-curing ultraviolet light curable resin by irradiating ultraviolet light; a third step of applying a printed layer of a pre-determined pattern to the surface of the pre-cured coating with a light insensitive non-transparent printing ink; a fourth step of irradiating ultraviolet light to the product obtained in third step to cure completely part of the pre-cured coating on which the printed layer is absent; and finally dissolving or peeling the incomplete cure layer and the printed layer to form the desired pattern on surface of substrate. This method is one of the effective methods to produce plating on selective area. However compare with the method by Uchytill et. al, this method is more expensive due to the additional cost need to produce insensitive non-transparent printing ink on the pre-cured coating.

Precision spot plating process and apparatus has been explained by Beck (1983) on US patent 4367123. In that patent, an apparatus for selectively electroplating at least one spot of metal on a substrate (lead frame) without substrate masking have been mentioned. The apparatus comprises a nozzle head which act as anode and direct connected to terminal positive of power supply. Mean while the outlet opening space for the nozzle head will determine the size and shape for the plating spot. The nozzle head is connected to the electrolyte reservoir by a pipe and with a valve to control the flow of electrolyte to the nozzle. The electrolyte is supplied by force of gravity with a desired hydrostatic head pressure. To control the hydrostatic head pressure, transparent container for electrolyte reservoir is used, and the photodetector and light source is used as a sensing device to control the height of the electrolyte in the reservoir. Consequently, it controls the hydrostatic head pressure for the electrolyte. If the height of electrolyte in reservoir is below the required value, the photodetector will activate the electrolyte pump which pumps the electrolyte from collecting tank to reservoir. The electrolyte will flow to the nozzle head with the hydrostatic head pressure in the range between 1 to 3 psi when the valve is open. It forming unmasked flowing through the nozzle opening and impinges on the surface of substrate which connected to negative terminal of power supply. When the power is on and the current supply is efficient, plating will happen on the impingement point and spot of metal will deposits on that point. The size and shape of spot has a dimension approximate to the size and shape of nozzle opening. The nozzle opening is placed as close as possible to the substrate in order to limit the travel distance of the electrolyte stream and reduce the electrical resistance of the stream. However, a minimum distance between the nozzle opening and substrate (5~10mm) must be maintained in order to avoid an electrical shorting effect and eliminate splashing of the electrolyte on substrate. The electrolyte will be collected by collecting tank after impinge on the substrate. This method eliminate masking process, thus reduce the cost of masking material and the setup time for masking.

Silver plating process for lead frames has been described by West et. al (1995) in US patent 5403466. In this patent, a method of providing selective silver plating to a lead frame has been mentioned. The disclosed method includes the steps of applying a layer of photoresist to a lead frame surface, exposing areas of the photoresists to ultraviolet light to define desired plating pattern, developing the photoresist (expose to ultraviolet light) to uncover the lead frame at the selected region, and plating the surface of lead frame which uncover by photoresist with silver coating. The method further includes subsequent steps of stripping the layer of photoresist after completely plate. This method is similar with the method invented by Uchytill et. al, the only different is during the exposing step. In this method, the exposing photoresist will be removed from surface of lead frame to form desired pattern, while in the method mentioned by Uchytill et. al, the unexposed photosensitive material will be removed to determine the pattern.

In the paper by Ho et al (1997), research of a method to selectively deposits silver coating on copper lead frames has been done. In this method, copper lead frame is first dip or spray coated with a polymer coating. Then, a laser beam is used to selectively ablate the coating and expose a desired pattern of bare copper substrate for electroplating. In this method, the pattern can be changed easily by computer programming or by simple beam shaping and masking techniques depending on the type of laser and laser optics used. This novel laser patterning process eliminates the use of toxic cleaning solvents and the delicate rubber masks which need to be replaced regularly. This laser process can be integrated into a lead frames electroplating production line with extra benefits in cleaning of surface contaminants, reducing production floor space and the amount of acid fumes, as well as eliminating the rubber mask alignment process and setup time.

DISCUSSION

According to the process review for existing selective plating methods in lead frame manufacturing industry, summarize can be made by categorized these methods to two groups i.e. masking and spot plating process. In masking process, two type of masking methods can be used. First type is called rubber masking which the rubber mold with desired plating pattern will be pressed together with the substrate before dip into the plating solution. Even though this method is more common technique use in lead frame industries, there are several limitations since masking increases the complexity and cost of the process and is a contributing factor to limited pattern resolution. Besides that, it is difficult to seal the rubber mold with lead frames by uniform compression pressure and this cause non-uniform deposit on lead frame. Furthermore, thermal expansions of the rubber mold during plating process also cause the change of geometry for the pattern at rubber mold. Consequently, this cause inaccurate plating on lead frame.

Due to the limitation of rubber masking, second masking method was developed. The improvement method is almost similar with rubber masking. Instead of using rubber mold, the chemical such as photoresist or photohardenable material was coated together with the substrate and forms a desired plating pattern on the surface of substrate before dipping into the plating solution. However, this method involve more complex process step, thus the cost is higher than normal masking process and only used for high end product.

Spot plating is a highly efficient and economical process since plating only occurs in small selected areas on lead frames without masking substrate. In this method, the electrolyte was continuous impingement to the substrate through a nozzle. The substrate is connected to negative terminal and the nozzle is connected to positive terminal of the power supply. Thus, the substrate will act as cathode and nozzle will act as anode in the electroplating process. During the electrolyte impingement to the substrate, the current is supply to the system through the power supply. If the current supply is efficient, then plating will happen and the nozzle outlet will determine the plating pattern. Compare with the masking method mentioned before, this is a more simple and low cost process. The elimination of masking often simplifies the treating process and eliminates any masks replacement or cleaning steps. However, it was still not use in mass production line because in the past the plating areas are large and masking method can be used efficiently.

CONCLUSION

In lead frame manufacturing process, electroplating technology is used to selectively plate a precious metal on the certain portion of lead frame. There are few methods can be used to selectively plate on lead frame and these methods can be categorized to two groups – masking and spot plating.

All these methods have the advantages and limitation. In term of cost, spot plating is the more saving method since it eliminates the use of masking process. Elimination of masking process not only reduces the cost for masking material, but also reduces the process step and the process setup time. Chemical coating masking is the more expensive process compares with the others two methods. The masking material such as the photoresist is expensive and most of the masking material could not be recycling after used. Since this method involve high cost, thus it only suitable for high end product.

In term of the plating accuracy and efficiency of, coating masking can provide better and higher quality plating compare with the other methods. While, the selective plating by rubber masking method normally need some finishing process to repair or cleanup the excessive plating.

Mean while in term of pattern resolution, spot plating can performed plating with any pattern with fast and simple change in the system. Different plating can be plated by only changing the nozzle path. While in rubber masking, one mask only can be used for one pattern. The time to setup the mask is more longer compare with the others.

By comparing these two selectively plate methods, it can be concluded that both have their own advantages and limitation. But in term of flexibility, cost and also process step, spot plating might be the better technique. Even though this technique still not use at the lead frame production line, but it will become relevant in future lead frame production since IC chip is getting smaller. Thus research on spot plating is very important for the advancement of semiconductor manufacturing industry.

ACKNOWLEDGMENT

The financial assistance from Universiti Sains Malaysia Fundamental Grant (Grant No. 6070011) is gratefully acknowledged.

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