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Research Article

Factor Effecting Electro-Deposition Process

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Abstract

The growth of electronic industry as a whole, and the demand to support the expansion of its underlying infrastructure will continue to drive the improvements in electrode position process. In order to improve existing electrode position process, the study of fundamentals aspects for electrode position process has become important. The influences of several electrode position parameters such as geometry of the path, the movement of electrolyte, pH factor, electrode position current, and bath temperature on the uniformity of the electrode position have been widely investigated. In this paper, the study of fundamentals aspect for electrode position will focus on Titanium oxide plating due to this process currently play very important role in semiconductor industry. In order to study the fundamentals aspect, a simple lab scale Nickel Titanium oxide plating experiment will be carried out to deposit a Titanium oxide coating on a Nickel electrode by using a Watts bath. Based on the experimental result, the influence of bath concentration and current density to the process current efficiency will be presented. By combining the suitable concentration and type of plating bath, amount of current density and appropriate anode, it will contribute to the enhancement of uniformity for the electro deposition. The optimum conditions of the deposition process are proposed at the end of the paper.

Keywords: *Electrodepostion, Operating parameter*

1. Introduction

Coating is a covering that can be applied to the surface of an object, normally called as substrate. The purpose of application of coating is the value enhancement of the substrate by improving its appearance, corrosion resistant property, wear resistance, etc .Process of coating involves application of thin film of functional material to a substrate. The functional material may be metallic non-metallic; organic or inorganic solid, liquid or gas.

2. Electroplating

Electroplating is one of the important processes in electronic industries. The original purpose of electroplating process is to enhance the value of metal articles by improving their appearance. However, the importance of metal finishing for purely decorative purposes has decreased. Currently, the trend is toward surface treatments which will impart corrosion resistance or particular physical or mechanical properties to the surface (e.g. conductivity, heat or wear resistance, lubrication or solder ability), and hence to make possible the use of cheaper substrate metals or plastics covered to give essential metallic surface properties or decorative for coating purposes (Pletcher, 1982).

Electrical relationships

Faraday's laws of electrolysis

Michael Faraday, perhaps the greatest experimental scientist in history, enunciated his laws of electrolysis in 1833, and these laws have remained unchallenged ever since. They are basic to both the understanding and the practical use of electrolytic processes. They may be stated as follows:

1. The amount of chemical change produced by an electrical current is proportional to the quantity of electricity that passes.
2. The amounts of different substances liberated by a given quantity of electricity are inversely proportional to their chemical equivalent weights. Equivalent weight is an older term, but still used widely in analytical and electrochemistry. In redox chemistry it is the molar mass divided by the number of electrons in the balanced redox half-equation.

Mathematically Faraday's laws of electrolysis can be expressed as:

$Q = z\, m/M$

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$Q = It = z\,Fn$

Where Q is the charged passed, I is the current passed, t is the time the current is passed, z is the change in oxidation state, m and M are the mass and molar mass respectively of oxidized or reduced species, F is the Faraday constant (96 485 C mol-1, the charge of one mole of electrons), and n is the amount of substance oxidized or reduced [Ken Osborne].

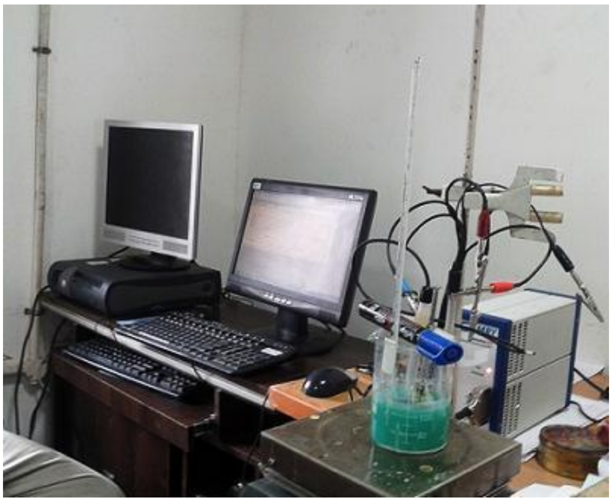

Fig: 1 Setup of Electro deposition process

3. The Purposes of Electroplating

Some of the purposes for which articles are electroplated are:

(1) Appearance
(2) Protection
(3) Special surface properties
(4) Engineering or mechanical properties.

The distinctions between these aims are not, of course, clear-cut and there are many Overlapping categories. A deposit applied purely for appearance must be, at least to some extent, protective as well. But the classification is convenient. Some finishes are purely decorative. Many objects meant to be used indoors, in a dry environment and where danger of corrosion is slight, are nevertheless finished with lacquers, paints and electroplated coatings for purely aesthetic reasons. The very thin layer of gold applied to some articles of inexpensive jewelry has little or no protective value; it is there principally to attract a potential buyer. There are many applications of electroplating; some of them of increasing importance at present, in which neither corrosion prevention or decorative appeal is the reason for using a finish. Copper is an excellent conductor of electricity and is therefore basic to such items as printed circuits and communications equipment. It does, however, quickly form tarnish films that interfere with joining operations such as soldering and that also render contact resistances unacceptably high in relays and switches. To make soldering easier, coatings of tin or tin-lead alloys are often applied to copper, and for better contacts over plates of gold are frequently required. Other surface properties may call for modification; if light reflection is important, a silver or rhodium plate may be necessary. In wave guides for radar, high electrical conductivity is the most important criterion, and silver is the preferred coating.

Good bearing properties may require coatings of tin, lead or indium. If a hard surface is required, chromium or nickel usually will serve. These few examples illustrate another use of metal finishing; to modify the surface properties, either physical or chemical, to render them suitable for the intended use. An all-nickel automobile bumper would render the car a luxury for the rich, aside from the fact that the required amount of nickel would probably be unobtainable. A tin can made entirely of tin would not only be more expensive than the good inside, but would also have no physical strength; tin is a very soft and weak metal. Chromium in massive form is almost impossible to work into useful shapes. In summary electroplating allows the use of relatively inexpensive metals like steel and zinc for the bulk of the article, while affording to the exterior the selected properties of the coating chosen.

4. Factor Effecting Electroplating

1. pH
2. Temperature
3. Current density
4. Time
5. Metal Ions
6. Concentration Bath
7. Agitation

4.1 Effect of Current Density and Distribution

In the electro deposition process the uniform coating of specimen is depend upon the current distribution parameter. In general, the metal ions are attached to the cathode at certain favored sites. This condition will possibly result to the presence of discontinuities in the form of pores, cracks or in other irregularities. Thus, In Electro deposition, current density and its distribution parameter play a centrally important role in determining the uniform coating of the final deposit. In the electro deposition process the current density over a cathode will vary from point to point. Current tends to concentrate at edges of the object. It tends to be low in recesses, vias and cavities because current tends to flow more readily to points nearer to the opposite electrode than to more far points. In the Electro deposition process cathode current density must be held within the proper interval with respect to bath composition and temperature. Insufficient current for given specimen will result in poor coating, while the presence of excessive current does not necessarily result in increased plating rate and is liable to create other difficulties. Low current densities tend to result higher impurity presence in the deposits. The reason for this is that once over the limiting current density for good deposition, hydrogen ions discharge occurs, that in turn; increase the pH level at cathode and-causing metal hydroxide ions to be included in the deposit coating. To summarize, the optimum current density range for given plating bath is depending on composition of salt, operating conditions and the type of the plating sought. Anode current densities are also an important plating parameter and should be controlled properly. This can be done through the adjustment of the total anode area and the proportion of it made up of the metal being deposited.

4.2 Effect of pH

The value of pH is depending upon the composition of Bath. The pH value should be maintained for good result. The pH of the bath influences the hydrogen evolution voltage, the precipitation of basic inclusion, the decomposition of the complex or hydrate from which the metal is deposited, and the extent of adsorption of additives. In a complex bath, pH may influence equilibrium between various processes. When the anode is insoluble, oxygen evolution takes place at the anode

$2H_2O \rightarrow O_2 + 4H^+ + e^-$

On the other hand, hydrogen evolution at the cathode is accompanied by the production of hydroxide ion:

$2H_2O + 2e^- \rightarrow 2OH^- + H_2$

In a neutral bath, if the current efficiency is greater at the anode than at the cathode, the bath becomes more alkaline. If the electrode efficiencies are similar, the pH of the bath remains unchanged. Hence change in pH of a plating bath is a good indication of electrode efficiencies. In certain conditions precipitation of metal hydroxides may occur locally within the cathodic double layer, which get co-deposited with the plated metal and give defective deposit while increasing the pH due to hydrogen evolution. Thus buffers are necessary to minimize these pH changes. During Electro deposition of aqueous solution, hydrogen ions are discharged together with the ions of the metal being deposited. The hydrogen evolved not only has a detrimental influence on the plating rate and on the cathodic current efficiency, but it often also unfavorably affects the structure and properties of the metal being deposited by causing spongy or powdery deposits, pitting or other defects. In the Electro deposition, the metal of iron group or the-metal with 'low hydrogen overvoltage are very sensitive to the Concentration of hydrogen ions in the electrolyte, a change in the pH value considerably affects both the cathodic current efficiency and the structure of the electrodeposits. The pH value of the cathodic film is not always the same as that of the bulk of the electrolyte. The Hydrogen ions take part in the electricity transport and also affect the changes taking place in the electrode film. The pH value of the cathodic film will in principle be higher than the bulk of the Electrolyte, if the number of hydrogen ions transported by the current is smaller than the number of the hydrogen ions discharged in unit time and vice versa. A change in the pH value of the cathodic film causes diffusion, which tends to equalize the activity of the hydrogen ionic discharged in the bulk of the solution and in the cathodic film.

The difference between the PH values of the cathodic film and the bulk Solution, which tends to increase with the current density, either become stabilized or continues to increase, depending on the composition of the solution. [Lainer, 1970]

4.3 Effect of Temperature

In general, an increase in bath temperature causes an increase in the crystal size. Increase in bath temperature increases solubility and thereby the transport number, which in turn leads to increased conductivity of the solution. It also decreases the viscosity of the solution, thereby replenishing the double layer relatively faster. High bath temperature usually decreases less adsorption of hydrogen on the deposits and thereby reduces stress and tendency toward cracking.

By increasing the bath temperature from 45°C to 55°C, the grain size of deposit partial decreased, whereas further increase of bath temperature resulted in a contrary effect.

4.4 Effect of Bath Concentration

Generally, in the Electro deposition process, bath concentration playing an important role to the plating performance. In normal plating condition, the increase of bath concentration will increase the Concentration of metal ions in solution. Therefore it will increase the deposition rate of the plating process. [Tan and Lim (2002)]

4.5 Effect of Plating Time

In general, the plating thickness is increase directly proportionately to the plating time and current According to the Faraday's Laws, quantity charge flow, Q in the solution is proportional to the current flow, l and also the Flow time, t as show in equation below: {Dahotre & Sudarshan, 1999].

$Q = I \times T$

4.6 Effect of Agitation

In General agitation provides sufficient mixing of metal salt so that the chemicals reagent becomes intimate and reacts with each other. In general, agitation of the plating solution replenishes metal salts or ions at the cathode and reduces the thickness of the diffusion layer. It reduces the gas bubbles, which may otherwise cause pits. Agitation helps increasing the operating current density and thereby permits a higher operating current density. These factors influences the structure of the deposit metal ion and also increase in the concentration of the metal, since it more rapidly compensates for the loss of the metal ions through discharge at the cathode. In the plating process, although agitation sometime cause the formation of coarse-grained deposits due to the mechanical inclusion of sludge and other impurities suspended in the electrode, it permits to use at high current densities plating process. The intensity of agitation should vary proportionately with the current densities with all other conditions remain unchanged. To reduce the defect of coarse-grained cause by impurities in the electrolyte, agitation is often accompanied by filtration electroplating; agitation promotes the deposition of the noble metal on the cathode Process. In brief, agitation system can greatly improve the plating performance since it provides sufficient mixing of the metal salt for the plating solution. However, this is true if the other parameters in the solution are controlled properly. [Pnauovic & Schlesinger, 198l]

4.7 Nature of the metal

Based on the magnitude of polarization, metals can be classified into three groups. Group I consists of metals like Ag, Pb, Cd, Sn etc., which are deposited at an over-potential of a few milli volts and rough deposits are obtained with grain size greater than 10_{-3} cm. Group III consists of metals like Ni, Co, Fe etc., which are associated with a large electrochemical polarization and are deposited as dense deposits with the grain size of around 10_{-5} cm. Cu, Bi, and Zn constituting the II group are intermediate metals with respect to the over potential value and grain size of the deposit. The interaction of the substrates with the deposited metal differs and this affect the kinetics of nucleation and hence the number of grains per unit area.

Conclusion

In conclusion, the parameters such as current density, temperature, agitation system, bath pH, bath concentration and also plating time playing very important roles in the performance of the plating quality.Thus, to achieve the high quality plating condition these parameters must be studied properly. The under-standing of these parameters is important to the plater and can help them to set the optimum condition for the plating operation. By achieving the optimum condition for the plating solution, it can improve the plating quality and reduce the production cost. In general, high current density (below the limiting current density), high bath concentration, high bath temperature with the agitation is preferred to achieve the high cathode current efficiency. However, the detailed study must be carried out to get the optimum condition for these parameters. For the pH and plating time, there were no specify limitation but it is only depending on the type of solution used and regarded thickness in the process. However, the plating solution with alkaline base is most familiar since this type of solution has less effect caused by hydrogen evolution. several experiments were canied out by the researchers to study the effect of operating parameters in the electroplating process, such as Loshkarev, Gornostaleva and Kriukova have investigate the dependence of anodic and cathodic current efficiency on temperature, additives, current density and other electrolysis parameters for nickel powder deposition. Kuznin and Motosova have studied the conditions of the deposition of alternate nickel and copper or zinc or iron layers. [Calusaru,1979).

It is found that Generally pH, Current density, Temperature are important factor of Electrode position process .The uniform coating of specimen is depend upon the current distribution parameter. The pH value should be maintained for good result. By increasing the bath temperature from 45°C to 55°C, the grain size of deposit partial decreased. Agitation helps increasing the operating current density and thereby permits a higher operating current density. Agitation is also important it reduces the gas bubbles, which may otherwise cause pits. Agitation helps increasing the operating current density and thereby permits a higher operating current density.

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