<技術講演>

Electroplating for the Electronics Industry*

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When I was asked by your President to speak to you today I have long and careful thought to the subject I should choose. As some of you may know I have spent over six years in Korea and one of my main concerns has been the development of the electroplating and metal finishing industry. I hope that during my time here I have succeeded in making some small contributions to its development. During my stay in Korea I have seen a truly amaging rate of industrial development to which the metal finishing industry has made an important contribution.

But enough of the past-I want to consider the future. In thinking about this talk I asked myself What area of metal finishing would I aim at if I were in the business in Korea?' 'Which area is likly to produce the best opportunities for good business?' There are a number of good possibilities but one I feel stands out. That is the electronics industry. But what kind of work to aim at?

While there will undoubtedly be considerable work available for such activities as plating on plastics, zinc plating of chassis etc., I feel that the companies who will do best are those who aim at producing technically functional finishes for electronics components.

The present rate of growth of the electronics industry and the increasing sophistication of its product will ensure an excellent market for the companies who equip themselves with the more complex techniques and 'know-how' required.

The demands for finishes in this sector fall into three main categories-plating for semiconductor devices, finishing of printed cicuits and the plating of contacts of various kinds. They have one thing in common however-the specifications are very precise and require a much higher degree of technical competence from the plating company. Because of this the number of companies which can meet the specifications are much smaller and the competition for this work will be much less than is normal in the plating industry. This means that the prices which can be charged for this work can be much higher, thus greatly increasing profitability. This is indirect contrast to normal plating works in Korea where competition is strong and profits are low.

Semiconductor devices consist basically of a silicon or germanium chip of extremly high purity which has a precisely controlled addition of an impurity element to convert them to n-type or p-type semiconductors. Because of the extreme purity needed, it has been customary to remove surface contamination before sealing, by immersion in extremely corrosive reagents. Different companies have their own special preferences but the usual constituents were mixtures of concentrated hydrofluoric acid, nitric acid, acetic acid and sometimes bromine. Whereas glass and other rather chemically inert non-metals can be used for some parts, metal must be used for connections and in many cases a substantial part of the device is metal. The cheapest metal which can resist such reagents is gold. The price of gold means that the use of it as the solid metal is uneconomic, therefore plating is used. Gold plating will only be effective, however, if it is non porous. Its nobility means that if any base metal is exposed through pores it will actually increase corrosion producing corrosion products which will contaminate the device.

This has lead to much development work to pro-

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duce gold plating processes which will produce pore-free deposits. While porosity can be overcome by increasing the thickness of deposits so that lateral growth fills the pores, cost and in some cases technical factors limit the thickness of gold which can be plated.

With most metals the value of the metal deposited is a small part of the cost (labour costs, overheads, etc.). The intrinsic cost of gold makes it a significant part of the plating cost. For large scale electronics production it becomes absolutely necessary to deposit no more than the absolute minimum needed to reduce porosity to an acceptable level and to find ways to limit the deposit to the areas where it is necessary. To illustrate the point there are many companies in this business whose gold costs (as metal) run at several million dollars per year.

The use of gold for its acid resistance is no longer so important as other cleaning technics have been evolved, so why is it still used? The answer is metallurgical. Silicon and germanium the two main semicnductor materials forms with gold a very simple binary alloy system with a eutectic melting point below 400°C. The two above elements alloy systems readily react with gold at temperatures only a little higher than the eutectic temperature and this provides an excellent method for joining the semiconductor device to the header or lead frame. This can be done in a matter of seconds.

The gold deposit obtained from the traditional cyanide gold bath was well suited to the process probably because of the relatively rough surface. This gives localized pressure points where alloying begins and these spread rapidly in a lateral direction. The problem with the bath is that although it will tolerate metallic contamination it needs very careful control to produce consistently acceptable results.

Most of the bright acid gold solutions which are suitable for decorative plating or plating of certain types of contacts or printed circuit boards are not suitable for this purpose. These are hardened and brightened by the addition of transition elements particularly cobalt and nickel. These are harmful to the semiconductor material but an additional and perhaps more important reason is that the smooth, often laminar deposits do not alloy as readily with the semiconductor material and may form ternary alloys which are brittle and can interfere with the bonding process. For this reason special gold plating solutions have been produced for this purpose which give quite bright but high purity gold deposits, with low porposity and good bonding properties.

These solutions are based on complexes such as sulphates, phosphites, polyphosphates etc. and frequently have small additions of such elements as indium or arsenic, which are themselves used for doping semiconductor materials and are, therefore compatible.

Special gold plating solutions have also been produced for plating headers. These cans with many legs (connectors) are barrel plated, but because of their form they tangle together and do not turmble readily in the barrel. This means that they may be out of contact with the cathode lead for a considerable periods. The gold deposits are substantially inert in the solution and do not passivate. The solutions are designed to limit the spread of thickness thus reducing the maximum thickness which must be plated thereby saving gold.

A major related area is the gold plating of lead frames for integrated circuits. This is now one of the major applications of plating in the electronics components field and will undoubtedly grow in the future. Gold plating over the whole lead frame is not essential and although this is still done, the trend is to limit the gold deposit to the essential areas by selective plating (or spot plating). Gold savings of up to 90% can be achieved in this manner.

Two main methods have been used for selective plating–application of a resist (photosensitive or screen printed) or the use of mechanical masks. The first method, while it is suitable for samller quantities, is expensive in terms of materials. The second method is faster and cheaper in terms of operating costs but involves more in tooling and is therefore more expensive to set up. Firstly however, we must consider the nature of the basis-metal and the technical requirements demanded of the gold deposit. The purpose of the deposit in mainly for die attachment or bonding as already described. Technical specifications call for ultra pure gold—a minimum of 99.9% purity or thereabouts. Thickness specifications vary somewhat but are usually 1 or 2 micrometer. In addition to die attachment the gold must be suitable for wire bonding—the welding of fine wires from the integrated circuit die connections to the leads of the frame. The most common functional test is the heat soak which calls for the gold coatings on the nickel-iron alloy frames to withstand a temperature of 500°C for 5 minutes in air without discoloration or blistering of the gold. As die attachment is performed in seconds this seems perhaps an over severe test but it is the normally specified test and thus must be passed.

To produce an ultrapure gold deposit which will meet these requirements special gold solutions have been produced. They must be capable of tolerating limited contamination with the least iron and nickel wtihout these metals 'plating out' in the deposit. For this reason they are near neutral or slightly alkaline solutions and often contain complexing agents to selectively complex multivalent transition metal contaminants to prevent them 'plating out'. It must be remembered however that the tolerance of any solution to these impurities is very limited and every precaution to prevent contamination must be taken. The discolo ration during heat soak is due either to diffusion of iron or nickel through the deposit and subsequent oxidation on the surface, or oxidation of codeposited impurities. It is also reported that cyanide derivatives can be codeposited resulting in the formation of carbon films on the surface during heat soak.

The speed of plating is also of great importance as usually large production is required. This means that high cathode current densities should be used with the maintenance of high cathode efficiences (approaching 100%). This should preferably be done without high gold concentrations in the electrolyte. High gold concentration increases the cost of the electrolyte and increases drag out losses: Gold concentrations are typically 8-10g/l although much higher concentrations have been used.

Selective plating machines are frequently used. They incorporate masks which confine the plating to the essential areas and pump a jet of electrolyte across the face of the workpiece. Cathode current densities approaching 9A/dm^2 can then be used at 100% cathode efficiency and very consistent results obtained. Current densities of as high as 60A/dm^2 have been used but results are not consistent. The jet velocities employed are frequently in excess of 1,000cm/sec.

The development of the plug in printed circuit board module has resulted in a demand for plated contacts. The plug is the board itself and the contacts are a series of fingers printed along one edge of the board (one side or both sides). The socket is a moulded carrier for a series of matching spring contacts. In principle the copper of the laminate could be used for the plug contact and the phosphor bronze or beryllium-copper spring for the socket. In practice however, the developmment of electronic devices which operate in circuits which frequently employ only millivolts, has meant that contact resistances have to be very small and stable. This requires a direct metal to metal contact with no surface corrosion films in between. This could be achieved at a high contact pressure but in practice the frictional force to insert or withdraw a board having, say 10 contacts, would be too great. In addition it is extremely difficult to ensure that each contact has the necessary contact pressure. If this happened it would probably result in failure of the entire instrument.

Again gold is the cheapest material for most purposes which meet the requirements. Rhodium, palladium, ruthenium, or platinum have been used in special cases. As gold is such a noble metal it has little or no tendency to form surface films. An adequately low and stable contact resistance can be obtained with contact pressures of only a few grams.

Again not all gold deposits are equally suitable for contact applications. Edge connectors or the printed circuit board are normally plated with a fairly high purity gold of moderate to low hardness, while the spring contacts are plated with a harder, low alloy gold. Connections are sometimes plated with a tin nickel alloy (or sometimes nickel) and over plated with a thin layer of gold. The hardness of the gold then is of less importance, as it is supported by the harder undercoating.

One other aspect of gold plating on electronics component and printed circuits must be mentioned. Gold is a very easily soldered material. It wets and forms strong joints easily even after even after components have been stored for long periods. This is a highly desirable property. But gold has one great disadventage in this respect, it dissolves very readily in tin/lead solder, this is why it wets easily; However, *gold and tin form an intermetallic compound* $AuSn_4$ which is extremly brittle. It solidifies immediatly on formation in the form of long needle like crystals. These tend to form at the gold solder interface and present a plane of weakness. This can result in fracture of the joint when the instrument is subject to shock or vibration and so loss of electrical connection will occur. For this reason many components which have to be soldered often, have a specified maximum thickness of gold (about 1.25 microns).

Other areas of interest to platers involve the production of their hole plated printed circuits and the application of tin/nickel, tin/lead ect. to circuits as etching masks and aids to solderability.

강연자 소개

Peter C. Ryder씨는 영국 University of Aston 에서 공업화학으로 B. Sc, *Birmingham College of* Advanced Technology 에서 Diploma of Technology 를 취득 했다. Engelhard Industries Ltd., U. K. (1963~68)을 거쳐서 1968년 부터 최근까지 구로공단에 있는 한국정밀기기 센타에서 UNESCO Training Adviser로 재직 하고 있었다.

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