Plating in the Electronics Industry

REVIEW OF SELECTED PAPERS GIVEN AT THE 9th AES SYMPOSIUM

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The analysis and control of gold plating baths used in the fabrication of electrical components and printed circuit boards were highlighted at the American Electroplaters' Society's 9th Symposium on Plating in the Electronics Industry held in Atlanta, GA., on February 16th and 17th, 1982. Electronic systems are becoming more complex with greater packing densities and are operating under stringent conditions. It is therefore becoming increasingly critical to optimize, monitor and control existing plating systems, to develop new materials and, at the same time, to work under environmentally acceptable conditions.

Solution Analysis

Two electrochemical techniques showing significant promise in monitoring gold and other plating solutions, cyclic voltammetric stripping (CVS) and differential pulse (DP) polarography, were discussed by R. Haak, C. Ogden and D. Tench (1, 2). The former method (1) may be used to determine the concentration of levelling and brightening agents from the effect such additives exert on the deposition rate. In the CVS method, the potential of an inert rotating electrode is cycled between fixed limits, so that a small mass of metal is alternately deposited on the electrode and then stripped by anodic dissolution. The stripping peak area in the resulting current density against electrode potential diagrams is proportional to the average deposition rate. Holding the electrode stationary lowers the concentration of additive at the electrode, thereby approximating to a zero-additive condition, while rotating the electrode provides a uniform concentration of additive at the electrode/solution interface. The ratio of the areas of the stripping peaks recorded under stationary and rotary conditions, respectively, provides an accurate measure of the effective additive concentration. The benefits and uses of the method were shown to include:

- (1) An absence of interference from other bath constituents
- (2) The ability to take into account automatically the decreased additive efficiency caused by interfering contaminants
- (3) The ability to provide direct measurement of electroactive bath species
- (4) The ability to control plating systems to provide consistent deposit characteristics.

The second paper described the use of DP polarography (2) to determine the concentrations of nickel and cobalt chelating compounds in hard gold plating solutions. The method provides a basis for controlling both the bath operation and deposition chemistry. The advantage of the method

over conventional analytical methods such as atomic absorption, colorimetry or gravimetric analysis is that it provides a simple, accurate and sensitive means of determining the total metal content, as well as the concentrations of the metals in their various oxidation states. An illustrative example was given showing how, in a hard gold plating bath, the alloying constituents, cobalt(II), cobalt(III) and nickel(II), could be detected without interference from gold complexes. Using a static mercury dropping electrode and a polarographic analyzer an initial polarogram (microampères against potential) is generated. The magnitudes of the peaks at -0.1 and -0.5 V are noted for cobalt(III) and nickel(II), respectively. The nickel(II) concentration is determined by comparing the peak area value to a calibration curve or by standard addition analysis. The bath is then treated with lead dioxide to oxidize the cobalt(II) to cobalt(III). A second polarogram is generated and the cobalt(III) peak is again noted. Standard addition analysis is repeated to determine the concentrations of both cobalt species. This method, used in conjunction with polarographic procedures developed for gold(I), gold(III) and uncomplexed cyanide species (3) permits the determination of all important bath species.

Engineering Considerations

Several papers presented were concerned with improvement of engineering aspects involved in the fabrication of printed circuit boards, and were aimed at a more efficient use of the gold on these. Much attention centred around the production of multilayer boards (4 to 7). These circuit boards provide improved reliability and reproducibility, while reducing the number of solder connections, space, mass, and costs. The development of the fabricating process was reviewed by M.W. Jawitz (4) who discussed the technical improvements which had taken place in chemical treatment, preparation of the polyimide coverlay lamination film, laminate lay-up process, drilling, plasma etching and plating procedures.

Surface Analysis

In electronic applications the properties of surfaces and electrodeposited films, including those of gold, on them are of critical importance. D.R. Marx (8) described how micro-physical properties of surfaces can directly affect macro-properties such as resistance to corrosion, wear and electrical conduction, bondability, reflectivity, colour, and catalytic activity. Several techniques for characterizing these surface properties were explored and examples were given of their use in the plating industry. X-ray diffraction is used to determine crystal structure, alloy phase structure, preferred orientation and crystallite size of deposits such as gold. The most commonly available surface and analytical methods are scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS). These are vital tools for characterizing the morphology and surface chemistry of electrodeposits such as those of gold. H.B. Mick, Jr. described the usage of SEM as a quality control technique (9).

For greater sensitivity in surface analysis, Auger electron spectroscopy (AES) and electron spectroscopy for chemical analysis (ESCA) are gaining wide acceptance in the study of films and surfaces (8). Analyses of surfaces to a depth of only 200 nm yield information about adlayers, chemical bonding, and atomic distribution. One of the examples cited showed how these techniques were used in studying the surface degradation of gold electrodeposits via grain boundary diffusion of the substrate metal.

Preserving, Cleaning and Disposing of Solutions

A number of papers dwelled upon cost savings made possible by various methods of treatment of gold solutions. These included extending plating bath life (10), removing contaminants from process solutions (11) and recovering gold from ion exchange resin (12). A further paper discussed U.S. governmental regulations on effluent wastes. A novel method of extending gold plating solution life was discussed by H.H. Law (10). Maintaining the correct solution chemistry was shown to be assisted by removing potassium ions that gradually build up in acid gold plating solutions. The removal was effected by separating acids and bases in a method known as Donnan dialysis. A cationic membrane in the form of a tubular coil was used and an acid solution flowing through the coil stripped the potassium at the membrane. In a phosphate-buffered bath the steady state fluxes of potassium ions removed were reported as 3.9×10^{-4} and 4.3×10^{-4} moles/cm².s at 20 and 40°C, respectively. In citrate-buffered solutions the respective fluxes were 1.4×10^{-4} and 2.6×10^{-4} moles/cm².s at 20 and 70°C. Further investigations were reported to be in progress involving scale-up and extended operation studies.

An updated review of filtration systems was given by

J.H. Berg (11) who noted a number of improvements in this technology. Wide ranges of sizes and materials are available to the plater to meet all filtration requirements. The amounts, sizes and kinds of suspended solids must be considered in choosing the proper system. Organic and some inorganic contaminants are removed by adsorption with activated carbons. Other impurities may be removed with ion exchange resins. The recovery of gold from these resins is of significant economic importance and one method outlined by G. Lindsay used an 'environmentally acceptable' metal-lined rotary furnace system with continuous feed capabilities (12).

The United States Environmental Protection Agency (EPA) regulations represent a major driving force behind the achievement of environmental acceptability by the gold plating industry, among others. Waste water treatment requirements for the electronics industry were reviewed by R.S. Cappacio (13). Current and future regulations were presented, listing governmental requirements to be imposed by 1984. However, local and State authorities can impose compliance with regulations before the federal compliance date. In some cases this has already been done.

In conclusion, this symposium can be rated as most successful, attracting an attendance of over 200 delegates and offering a well balanced technical programme. A total of eighteen papers was presented. The major philosophy developed during the symposium was the need to analyze, optimize and control gold and other plating baths used in the fabrication of electronic components. It is apparent that a considerable research and development effort is being conducted which is aimed at achieving higher product quality and reliability.

References

- 1 R. Haak, C. Ogden and D. Tench, 'Optimizing and Controlling Circuit Board Plating from Acid Copper Sulfate', Symposium paper
- 2 R. Haak, C. Ogden and D. Tench, 'Polarographic Analysis for Organometallic Additives in Hard Gold Plating Baths', Symposium paper
- 3 Y. Okinaka and C. Wolowodiuk, *Plat. Surf. Finish.*, 1979, **66**, 50-54
- 4 M.W. Jawitz, 'Fabrication of Rigid Flex Multilayer Boards — A Typical System', Symposium paper
- 5 W.R. Brasch, W.F. Sepp and B.L. Nobel, 'Factors Affecting Electroless Copper Coverage on Multilayer Through-holes', Symposium Paper
- 6 D.A. Rudy, 'The Influence of Circuit Configuration on the Uniformity of Pattern Plated Wiring Boards', Symposium paper
- 7 G. Arneson, 'Optimum Telemechanical Positioning for Material Handling Equipment', Symposium paper
- 8 D.R. Marx, 'Recent Advances in the Analysis of Plated Films and Surfaces', Symposium paper
- 9 H.B. Mick Jr., 'Monitoring Dry Film Photoresist Characteristics for Optimum Performance in Plating by Analysis of Photoresist Sidewall Shape', Symposium paper
- 10 H.H. Law, 'Extending the Life of Gold Baths by Donnan Dialysis', Symposium paper
- 11 J.H. Berg, 'Removing Contaminants from PC Process Solutions', Symposium paper
- 12 G. Lindsay, 'Recovery of Gold from Ion Exchange Resins', Symposium paper
- 13 R.S. Cappacio, 'Wastewater Treatment for the Electronics Industry', Symposium paper