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Development of a technological process for electrodeposition of uniform copper coatings in PCBs holes

Abstract

Relevance of the research

Printed circuit boards (PCBs) are an integral part of modern electronic devices and equipment and consist of a dielectric plate (fiberglass, synthetic resin bonded paper, etc.), on the surface and/or within which electrically conductive electronic circuit are formed.

Taking into account the modern requirements for the dimensions and compactness of such products, multilayer printed circuit boards (MPCs), consisting of pressed alternating layers of a dielectric with an applied conductive pattern (CP), are becoming increasingly in demand in industry.

The CP is located both on the outer sides of the board and on the surface of the internal layers of the PCB, the electrical connection between which is carried out through metallization of the through holes of the PCB. Metallization includes the following stages: preparation (cleaning-conditioning, etching, activation), chemical copper plating, subsequent electrodeposition of copper. These processes play an important role in ensuring the reliability of printed circuit boards.

With the development of the electronics industry, the quality requirements for the multilayer printed circuit boards are becoming increasingly stringent; their design is becoming more complex and the accuracy class is increasing (GOST 53.429-2009). This leads to a decrease in the width of the CP tracks, the distance between the edges of adjacent conductors, the diameter of the holes and an increase in the aspect ratio - the ratio of the thickness of the board to the diameter of the holes (IPC-2221A and IPC-2222). In this regard, it is becoming increasingly difficult to ensure high-quality metallization of MPCs holes. The required technical characteristics of the PCB are largely ensured by the uniform distribution of the electrodeposited copper coating inside the holes and on the surface of the PCB. Copper plating of the holes of modern MPCs requires high-tech electrolytes with high throwing power (TP), ensuring uniformity of

the copper coating at a high value of the aspect ratio of the PCB.

Foreign technological processes for copper plating of MPCs use functional additives, the combination of which in the electrolytic solution makes it possible to achieve a high throwing power, ensuring a uniform coating in the holes of the PCB.

Domestic technologies for copper plating of printed circuit boards (GOST 23.770-79, OST 107.460092.028-96) do not meet the increasingly stringent modern requirements, in particular in terms of the coating uniformity in the holes, as well as that of the stability of the electrolytic solution. Russian manufacturers are forced to use imported technologies. The known disadvantages of imported compositions are their high cost and risk of sanctions.

In connection with the above, the development of domestic a technology for copper electroplating of printed circuit board holes, which meets the modern requirements and is not inferior in characteristics to foreign processes, is an important scientific and technical problem, to the solution of which the current dissertation work is devoted.

The degree of development of the research. The analysis of literature, including patents, showed an almost complete lack of information about Russian developments of copper plating solutions for printed circuit board holes with a high aspect ratio, as well as a lack of information about the influence mechanism of various functional additives on the technical characteristics of the coatings.

The purpose of the work

Develop an import-substituting copper electroplating technology, which would make it possible to obtain uniform, ductile coatings in the holes of high aspect ratio MPCs.

The research tasks:

1. Study of the influence of the concentrations of the main components of the base (mineral) part of the solution upon its throwing power.

2. Study of the influence of the nature and concentration of organic additives upon the copper reduction rate.

3. Study of the influence of the nature and content of organic additives upon the throwing power of the solution.

4. Study of the influence of solution composition and process parameters upon the functional characteristics of the coatings.

5. Study of solution stability.

6. Development of corrective concentrates and adjusting regime solution during operation.

7. Testing the developed technology in factory conditions.

Scientific novelty of the research.

1. It has been determined that all types of additives in sulfuric acid copper plating solutions that are used for the copper plating of printed circuit board holes, classified in the literature and in practice as «inhibitors», «levelers» and «accelerators», when separately introduced, inhibit the process of copper reduction from the sulfate solution. The inhibition of the copper reduction process from an solution containing an «inhibitor» is enhanced when an «leveler» is added to the solution, and is depolarized (weakened) when an «accelerator» is added. When adding an «accelerator» to the solution with an «inhibitor» and a «leveler», the depolarizing effect of the «accelerator» is to observed.

2. Using ellipsometric measurements, it was determined that the thickness of the surface film on a copper cathode deposited from a solution containing an «inhibitor» or «accelerator» additives does not depend on the polarization of the cathode (8–12 nm and 37–48 nm, respectively), and the thickness of the surface film in the presence of «leveler» additive in the solution is minimal in the absence of cathodic polarization (7–9 nm) and increases (up to 18–35 nm) with electrode polarization (by 200 mV). When the «inhibitor» + «leveler» additives are combined in the electrolyte, the thickness of the surface film on the polarized cathode takes on an intermediate value (13–17 nm) and practically does not change after adding the «accelerator» additive to the solution (12–17 nm), and when adding «accelerator» into a solution containing only an «inhibitor», the thickness of the surface film increases and approaches the thickness of the surface film for a solution with an «accelerator» (35–43 nm).

Practical significance of the research.

1. Additives to the copper electroplating solution for printed circuit board holes were experimentally established to ensure uniform thickness of copper coatings in the

holes and on the surface of the PCB: «inhibitor» – polyethylene glycol 4000; «leveler» – 2-diethylamino-3,6-dimethyl-9-phenylphenazonium-7-azo-4′-dimethylaniline chloride or polyethylenimine (Mw 25000 g/mol, branched); «accelerator» – sodium 3-mercapto-1-propanesulfonate.

2. An import-substituting technology for copper electroplating of through holes of printed circuit boards has been developed, which is not inferior to its foreign counterpart in terms of the uniformity of coating thickness, both inside the holes and on the surface of printed circuit boards, in terms of the gloss and ductility of the coatings, as well as in the stability of the electroplating solution.

Provisions for defense

The results are submitted for defense:

– studies of the influence of the nature and concentration of organic additives upon the rate of copper deposition.

– studies of the influence of the nature and concentration of organic additives on the throwing power of the electrolyte and the distribution of copper coating inside the holes of printed circuit boards.

– studies of the influence of additives on the leveling ability of the solution on samples with a regular triangular morphology.

– ellipsometric studies of surface films on a polarized copper cathode.

– studies of morphology, gloss, elongation and plasticity of coatings.

– studies of solution stability, as well as the mode of electrolyte adjustment during operation.

– electroplating solution testing at existing production facilities.