Bardina Olga Igorevna

Modification of copper surfaces for improvement if adhesion of internal layers and functional coatings of printed circuit boards

Abstract

Relevance of the research

The current trend toward increasing the power of electronic equipment while simultaneously reducing its size necessitates the placement of an increasing number of electronic components on a printed circuit board (PCB), as well as an increasing number of printed conductors connecting them. This can be achieved using multilayer printed circuit boards (MPCBs), the outer layers of which house numerous electronic components, and their connection is ensured by a conductive pattern formed on the inner and outer layers of the PCB.

The reliability of a MPCB is largely determined by the adhesion strength of the copper surface of the inner and outer layers of the MPCB to non-metallic coatings such as prepreg (an epoxy resin layer reinforced with a fiberglass frame), photoresist, and solder mask.

For reliable adhesion in multilayer PCB production, an adhesion layer is formed on the copper before key steps: inner layer lamination, and the application of solder mask and photoresist.

In modern technologies, adhesive layers are formed by microetching the copper surface to form a rough layer ~1.5-2.5 μm thick, which ensures the adhesion of layers not only by increasing the contact surface area, but also through chemical bonds with the polymer binder of the prepreg.

Over the past decade, the share of microwave printed circuit boards for electronic devices operating at high and ultra-high frequencies has been increasing. Formation of a rough adhesive layer on the conductive pattern of the inner layers is unsuitable for microwave boards due to the «skin effect». When transitioning to high frequencies, the thickness of the surface layer in which the electrical signal propagates, (skin layer) decreases, and consequently, the proportion of current passing along the surface of the rough layer increases. This increases the effective signal path and transit time, leading to a partial loss of signal power. To reduce the path length of high-frequency signals and reduce resistance, it is necessary to reduce the surface roughness of the conductive pattern of the inner layers, while maintaining the strength of its adhesion to the prepreg.

To modify the copper surface in order to increase the adhesion strength of the internal layers of the printed circuit board, as well as the adhesion of photopolymer coatings (photoresist and solder mask), domestic manufacturers are forced to use foreign technologies, since domestic technologies that meet modern requirements for the functional characteristics of the layer formed (adhesion, corrosion resistance, and for microwave printed circuit boards - minimal roughness), as well as for the processability of solutions (resource, stability, etc.) do not exist.

Taking into account all of the above, the development of technologies for the modification of copper surfaces in order to increase adhesion to non-metallic layers and coatings is a highly relevant scientific and technical goal, the solution to which is the subject of this dissertation.

Degree of development of the research topic. An analysis of scientific, technical, and patent literature revealed a virtually complete lack of information on Russian developments of solutions for the modification of copper surfaces to increase adhesion to non-metallic layers in the production of microprocessor-based printed circuit boards.

The purpose of the work

The aim of this work is to develop technologies for modifying copper surfaces to ensure adhesion of internal layers and functional coatings (photoresist, solder mask) on multilayer printed circuit boards.

The research tasks

1. The study of the influence of the nature and concentration of solution components, as well as process parameters, on the functional characteristics (roughness, friability, corrosion resistance, adhesion) of the forming layer and the copper etching rate.

2. The study of the service life and stability of etching solutions.

3. The development of solutions for adjusting the solution during operation.

4. Testing the developed technologies in a factory environment.

Scientific novelty of the research

For the first time, it has been demonstrated that adding chloride ions at a rate of 5-500 mg-ion/L to a copper etching solution containing sulfuric acid and hydrogen peroxide reduces the copper etching rate by 10-15 times. Adding benzotriazole to this solution significantly reduces the inhibitory effect of chloride ions on copper dissolution. This can be used to control the roughness of the adhesion layer to ensure maximum adhesion strength between the copper surface and the dielectric while minimizing its etching rate.

For the first time, it was established that during the treatment of a copper surface in a solution containing sulfuric acid, hydrogen peroxide, benzotriazole and chloride ions, along with the development of the microrelief of the copper surface, a metal-organic layer with a thickness of 200-300 Å is formed on it, the main components of which are compounds of Cu, C, N.

Theoretical and practical significance of the research

The theoretical significance of this work lies in establishing patterns of influence of process parameters, the nature and concentration of components of microetching solutions, on the etching rate of copper, the roughness of the resulting surface, and its adhesion to non-metallic materials.

Technologies for modifying the copper surface of the conductive pattern of the inner layers of printed circuit boards, including microwave printed circuit boards, before pressing in order to

ensure strong adhesion of the inner layers of the printed circuit board were developed.

Technologies for modifying the copper surface of printed circuit boards before applying photoresist and solder mask, which are not inferior to foreign analogues in terms of adhesion strength to these materials and manufacturability were developed.

Methodology and research methods

The methodology of the current work includes general theoretical and empirical methods of scientific research, including searching and analyzing literature on the topic of research, setting research objectives and determining appropriate methods for solving them, conducting experiments to identify key patterns and gain new knowledge in the area of study, analyzing the results obtained, and applying them to achieve the goals of the dissertation.

Provisions for defense

1. Research Results:

- Dependence of the functional characteristics of the adhesion layer (roughness, friability, corrosion resistance, and adhesion) on the solution composition and process parameters;

- Solution adjustment modes during operation.

2. The technological processes developed (and their implementation compositions):

- Surface preparation of the copper conductive pattern of the inner layers of printed circuit boards for pressing;

- Surface preparation of the copper conductive pattern of the inner layers of microwave printed circuit boards for pressing;

- Surface preparation of the foil-clad dielectric and conductive pattern before applying photopolymer coatings.

3. Results of testing the developed technological processes in an operating production facility.