Research of novel metal-polymer binding strategies in sequential build-up technology.

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Abstract Coming generations of portable electronic products will require significant improvement in interconnection technology due to increasing signal frequencies and demand for higher density of functions. Further miniaturization will require shorter and smaller interconnects between chips and other components. Polymers are frequently used for constructing build-up layers with microvia’s by either laser ablation or photolithography. Atop the dielectric polymer metal layers are plated by means of a wet-chemical electroless and/or electroplating process for industrial purposes. The adhesion of the plated metal layers to this polymer surface is of prime importance for the reliability of the interconnection. This research focuses on evaluating used adhesion improvement mechanisms and inventing new binding strategies for metal-polymer interfaces for electronic interconnections.

Keywords Interface, metal-polymer, electronics, build-up

I. INTRODUCTION

The ever increasing demand for higher interconnection densities on Printed Circuit Boards (PCB’s) has led to the development of so called sequential build-up structures (SBU’s) and micro-via technology. This research started in the late 90’s [1]. Conventionally made multi-layer laminate boards have a typical wiring density between 200 and 300 µm; a copper thickness of 35 µm on outer layers and vias of the plated through hole type with a diameter of 250 to 300 µm [1]. The wiring density is defined as the sum of the width of and the distance between copper interconnections (e.g. wires). However, to be able to mount unpackaged chips on the boards, through flip chip or wire bonding, a wiring density in the range of 100 to 150 µm is required. These dimensions are necessary for RF applications [3]. This can be achieved by a sequential build-up of alternate dielectric and copper layers atop of a normally finished multi-layer board (Figure 1).

Most of the printed circuit boards (PCB’s) used today are fabricated with a glass-epoxy resin, on which metals (usually copper) are plated and patterned in order to realize interconnections between different components placed on top of the substrate. Because of the continuing thrive in microelectronics to miniaturize and/or the necessity for electronic circuits to operate in harsh environments, a good adhesion between the copper and the polymer is of prime importance. It is obvious that the surface properties of the polymer are very important for the adhesion of the metal to the polymer. By chemical treatment of the surface the characteristics (physical and chemical) of it can be changed in order to improve adhesion. Since smaller dimensions of the typical interconnection pattern from the build-up layers on a PCB have a big impact on the reliability of wafer level chip scale packages, a good adhesion of metals on the build-up polymer layer is an important issue [4]. Hence there is an intense recent research into improving the adhesion of plated copper onto polymer surfaces. Because of the much lower prize of wet chemical treatments compared with composites or plasma (vacuum) processes, these treatments are preferred industrially.

Fig. 1. Illustration of build-up layers on top of a multilayer core.

II. ADHESION OF PLATED METALS ON POLYMERS

A. Influences on adhesion strength

The adhesion strength of metals on polymers consists basically out of 2 parts: physical adhesion and chemical adhesion. The physical part of adhesion is associated with mechanical interlocking, roughness of the surface, deformation of the polymer and metal layers, etc. The chemical part of adhesion is associated with the bonding characteristics and structure of the interface. In particular for metal-polymer interfaces the chemical adhesion part is distinct and interesting. A metal is characterized by an ordered atomic structure, while a polymer has a disordered and loose molecular structure. Interfacial adhesion of plated metals is also influenced by the chemical composition of the plating bath.

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B. Surface modification of polymers

In order to obtain better adhesion strengths of metals on polymers, the surface of polymers are modified using wet-chemical treatments. Industrially these consist of a combination of sweller (solvent structurally similar to the polymer that diffuses into the free volume of the polymer) and oxidizers (KMnO₄ and K₂Cr₂O₇). These treatments were examined in our research [5-7] using the following analyses:

- determination of the topography and physico-chemical mapping of the interface by Atomic Force Microscopy (AFM).
- determination of the surface polarity (hydrophilic/hydrophobic balance) by dynamic contact angle measurements: estimation of the surface energy (harmonic mean concept).
- chemical characterization by both ATR-FTIR and ToF-SSIMS
- determination of the oxidation state of the immobilized copper by XPS-analysis in order to follow up the reduction process.

Some of the most important results of our research can be summarized as:

- etching with oxidizing agents of the polymer surface introduces more polar groups at the surface
- polar groups at the surface react with the oxidizing agent and the difference in surface concentration leads to a difference in etching speed
- usage of sweller agent increases the number of polar groups at the surface. This causes an increase in the number of polymer break-down groups.

These wet chemical treatments have a pronounced effect on the surface roughness. Through the surface roughness it influences the adhesion strength [8]. Furthermore the type of chemical groups at the surface is changed, thereby influencing the chemical part of adhesion.

Sweller diffuse through the free volume of the polymer and induce a force field that creates more polar groups at the surface [7]. In this way swellers influence the oxidative treatment that follows it. The polar groups are the groups that are being etched away by the oxidation. A reaction scheme has been developed to explain the influence of these treatments on the surface topography and the chemical composition of the surface, as well as the mass loss of the polar surface.

A typical view of a treated surface is shown in figure 2.

![Fig. 2. A typical view of a treated surface.](image)

The chemical treatments typically changes the RMS (Root Mean Square) roughness of the surface from 10nm to 350nm and introduces COO⁻ and OH functions on the surface (detected by ATR-IR). According to literature [8] the adhesion strength of these chemical treatments is linearly correlated to the roughness of the surface. This is caused by the fact that the chemical composition of the surface does not change over reaction time [7-8], which means that the groups at the surface remain identical. However roughness is detrimental to the performance of high-frequency interconnections, so in future the roughness of the surface will have to remain limited.

In order to improve the adhesion strength of metals to polymers even further, a surface synthesis has been developed making it possible to introduce different types of chemical groups at the surface, thereby changing the chemical composition of the polymer surface. Using this technique the chemical part of adhesion is changed in order to provide adhesion without need for roughening the polymer surface.

C. Electroless plating

The main type of deposition used in our research is the wet-chemical electroless copper deposition. This process deposits a seed layer for electroplating. Compared to sputtered layers electroless deposited layers are much cheaper, but have lower adhesion strength. This is caused by the co-deposition/inclusion of impurities into the wet-chemically deposited copper. The goal of this research is to attain the adhesion performance of sputtered layers by using wet-chemicals.

III. CONCLUSIONS

The adhesion strength of metal layers on polymer surfaces depends on a physical and a chemical part. Traditional wet-chemical treatments focus on improvement of adhesion by increasing roughness- the physical part of adhesion. By changing the types of groups at the polymer surface the interface can be changed in a chemical way, thereby increasing the adhesion of metals to polymer surfaces. In this way adhesion can be further improved.

REFERENCES