Preface: Advances in materials and processes for printed circuit packaging technology

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The basic set of sciences related to printed circuit board production includes almost all of the basic disciplines of the materials scientist. This is well illustrated here in a set of papers encompassing studies in materials characterization, analytical chemistry, polymer chemistry, electrochemical reactions, surface phenomena, diffusion and permeation, mechanics, and metallurgy.

The following papers are a result of a significant collaboration among research, development, and manufacturing areas within IBM to increase the rate of learning in these disciplines.

- *Circuitization process sciences*

Horkans, Sambucetti, and Markovich report on their study of initiation of plating on nonmetallic surfaces. The basic principles involved are, of course, applicable to laminating resin materials. They have studied the most suitable catalysts, in organic colloids, based upon elemental Pd and Sn. Various electrochemical and analytical measurement techniques were employed to study the colloidal structure and its surface distribution in relation to the Pd, Sn distribution and their catalytic activity.

The mechanisms of electroless plating have been classified according to four overall reaction schemes by Bindra, Light, and Rath, who consider each partial reaction to be either under diffusion control or electrochemical control. They show that in electroless copper plating the copper deposition reaction is diffusion-controlled, while the formaldehyde decomposition is activation-controlled, and also deduce that these two partial reactions are not independent of each other. The formaldehyde decomposition mechanisms were further investigated in detail by Bindra, Roldan, and Arbach. They show that metals with positive, near-zero, or negative free energy of hydrogen absorption have different mechanisms for formaldehyde decomposition reaction.

A critical step in the circuitization process of printed circuit board is the immersion tin deposition, which converts the copper surface inside a plated through-hole into a surface easily wettable by melting solder. Kovac and Tu studied the chemical reactions in the bath, the surface film growth in the bath, and the resulting Cu-Sn metallurgies. It was shown that

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various chemistries in the bath produce different compositions of deposited tin. In one case the surface is readily wettable by molten solder, but not in the other case. The latter case would result in poorly filled plated through-holes in advanced circuit boards, which have a large aspect ratio of hole diameter to board thickness. An understanding of the chemistry and metallurgy is crucial to proper control of this complex process.

- *Materials characterization*

Gaseous evolution from the polymeric materials is of interest. Ginsberg and Susko report on the analysis of polyimide by mass spectroscopy techniques, and show how prebake and controlled temperature procession could significantly reduce gas evolutions at critical process steps.

Kim, Wen, Jung, and Johnson characterize the microstructure copper deposited on various substrates, including large-grained polycrystalline, single-crystal, and evaporated copper surfaces, as well as catalytically activated nonmetallic dielectric surfaces. It was shown that the initial microstructures of copper deposited on catalytically activated and evaporated films were similar, but very much different from those evolved from large-grained polycrystals and single crystals. This study clarified the copper growth mechanism and resulting mechanical properties in the composite circuit board.

It is important to know specific concentrations of some critical components in a multicomponent solution in any complex chemical plating process. One such method is reported by Schubert on a new analytical technique in multicomponent solutions.

- *Moisture in polymers*

A necessary ingredient of the loss of insulation resistance is the presence of moisture in the circuit board materials. It is important to understand the moisture absorption, desorption, and transport mechanism in the polymer resin materials. This knowledge can then be used to quantitatively optimize the process systems and environments of the resin-glass-copper composite circuit boards. It turns out that the mathematical characterization of the diffusion phenomenon is non-Fickian and depends on prior history. A quantitative mathematical model has been developed for the multistaged sorption and transport phenomenon of the composite system through several stages of temperature and moisture environments, as described in the paper by Marsh, Lasky, Seraphim, and Springer.

Berry and Pritchet demonstrate a simple but sensitive method for the study of water absorption and swelling in polymers, based upon the classical bilayer beam theory. They derive expressions for both the time-dependent and equilibrium curvature of the bilayer strip from which both the polymer resin diffusional and dilatational parameters can be deduced from experimental beam-bending data. This technique is used to characterize the circuit board epoxy resin diffusion coefficient, as well as the relation between expansion coefficient and humidity.

- *Mechanical modeling*

In the paper by Lee, Darekar, and Lim the multilayer printed circuit board is viewed as a composite system and modeled for stress distribution, temperature, and diffusion using finite-element techniques. Particularly important are internal buried program vias and stress distribution around the plated through-holes. In view of the small sizes of these design elements, special micromechanical testing techniques were developed to measure the copper-epoxy adhesion within a hole itself, as well as copper-copper bond strength. Mathematical modeling and micromechanical experimental mechanics are important tools to understand the process impacts on mechanical integrity of the circuit board. These techniques are also useful in the design and testing of the electronic package assembly. Since the stresses are usually induced by temperature and deformation, and the failure mechanisms in the process are sensitive to localized materials weaknesses, comprehensive mathematical modeling to follow the history of process and testing steps turns out to be a key element for design and process optimization. This is well illustrated in the paper by Kelly, Lim, and Chen in their work to optimize the mechanical interface between two layers of packaging.

- *Concluding remarks*

The foundation of advanced electronic packaging manufacturing processing is primarily based on materials and engineering sciences in their broadest interpretation. Further advances in packaging technology rest on corresponding advances in fundamental knowledge in materials science and process technology, as well as the tradition of close collaboration between the inventors and the implementers.

The goal was to establish a long-term set of improvements through fundamental materials, process, and design actions to allow continued incremental increases in density and performance. Thus the actions progressed from development of screens to ultimate implementation of sensors, monitors and controls, new materials, and improved processes, as well as some new tools. It was decided that these actions were necessary to reduce defects to such a low level that there would be nearly zero probability of interaction of a defect site with a risk site in the printed circuit board. Accordingly, the intent was to understand the source of all defects in the production line. Obviously, it is no longer satisfactory to make empirical changes to a complex manufacturing process. The in-depth understanding arising from the new techniques of failure analysis has thus been applied to numerous problems to provide development with the base it needs to evaluate new materials and processes.

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