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The Application of Phase Diagram for Interfacial Reactions in Electronic Packaging

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Abstract

The phase diagram investigation is basically scientific study of materials science and engineering. The basic materials knowledge, such as material thermodynamics and kinetic, phase transformation, and solid state diffusion can be used to explain the intermetallic compounds (IMCs) formed at the interface. Meanwhile, the phase diagram information is one of the important tools, as well. The phenomena in the interfacial reaction should be combined with the phase equilibrium information. Therefore, we can have a clear understanding of the interfacial reaction between the atomic diffusion mechanism and the final equilibrium condition. In the electronic packaging process, lead-free solders are Sn-based alloys, and the substrate is likely to be the Ni/Cu structure. During the soldering process, both Cu and Ni are rapidly dissolved into the molten solder, resulting in the concentration changes of Cu or Ni. The Cu concentration at the solder-joint would dramatically change before and after reflowing due to long heat-treatment aging or the solder-joint volume change. Professor Sinn-Wen Chen and Professor C. Robert Kao have report several studies on Cu concentration effect in the solder/Cu couple and obtained widely response from the industry. The IMC growth at the Ni side and IMC precipitation in the solder are very sensitive to the Cu concentration and aging time. In this talk, we describe the relationship between the interfacial reactions and the corresponding phase diagrams for the above systems. The soldering society would understand the importance of the phase diagram in electronic package.

Keywords: Phase diagram; Intermetallic compound; Interfacial reaction; Electronic packaging; Soldering process

Introduction

The Sn-Pb alloys have been used in electronic packing industry for many years due to their low liquidus temperature and low cost. However, lead is harmful to the environment and human health. Therefore replacing the conventional Sn-Pb solders with proper Pb-free solders is currently the most important issues in the electronic industry [1,2]. Sn-Bi [3-5] and Sn-Zn [6-8] alloys are the most common lead-free solders, because its binary phase diagrams is similar to the Sn-Pb alloy. And both of them are simple eutectic system. The eutectic temperature is about 139 °C, lower than the Sn-Pb alloys. Au, Cu, Ni has good mechanical and electrical properties [9-15]. Therefore, they are generally used as electroplating metal materials and the main under bump metallization metal layer materials in flip chip process. Clear understanding of the interfacial reactions can improve the solder joint strength. Meanwhile, phase diagrams are powerful and useful tools to understand interfacial reactions. Thus, related phase equilbria and interfacial reactions were investigated in this study [15].

Experimental Setup

High purity alloys with different compositions were prepared to determine the phase equilibria. Each alloy was encapsulated in a quartz tube in a 0.1Nm-2 vacuum and the sample tubes were placed in a furnace at specific temperature for aging. Solid/solid or solid/liquid reaction couple techniques were used to investigate the interfacial reactions between metallic substrate and lead-free solders. After reaction, all the samples were quenched in iced water, and then taken the metallurgical treatment to obtain the clear cross-section morphology. An optical microscope (OM) and scanning electron microscope (SEM) were used for microstructure examination. The SEM with an energy X-ray dispersive spectrometer (EDS) and the electron probe microscopy analysis (EPMA) were used for compositional analysis. The second half of the alloy specimen was pulverized and analyzed with an X-ray diffractometer (XRD) to obtain its diffraction pattern. From the JCPDS (Joint Committee of Powder Diffraction Standard) database, the phases in the alloy could be identified. Microstructures, compositional data, diffraction patterns and the phase information of the related phase diagrams were examined together to identify the phases present in each equilibrated alloy or reaction couple.

Results and Discussion

Phase equilibria of the Sn-Cu-Au ternary, Ag-Sn-Cu-Au quaternary systems and interfacial reactions between metallic substrate and lead-free solders were experimentally investigated at specific temperatures. The experimental results indicated that there existed three ternary intermetallic compounds (IMCs) and

a complete solid solubility between AuSn and Cu6Sn5 phases in the Sn-Cu-Au ternary system at 200 °C [9]. No quaternary IMC was found in the isoplethal section of the Ag-Sn-Cu-Au quaternary system. The IMC growth at the Ni or Au side and IMC precipitation in the solder are very sensitive to the Cu concentration and aging time [6-13]. Therefore, the electronic industry must assess their choice of the optimal solder composition and strictly control the Cn concentration to ensure the joints exhibit consistent with its interfacial properties. The information is very valuable for the soldering community.

Conclusion

We describe the relationship between the interfacial reactions and the corresponding phase diagrams for the above systems. The soldering society would understand the importance of the phase diagram in electronic package.

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