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Editorial

Emerging Interconnection Technology and Pb-Free Solder Materials for Advanced Microelectronic Packaging

Byungmin Ahn [1,2]

[1] Department of Materials Science and Engineering, Ajou University, Suwon 16499, Korea; byungmin@ajou.ac.kr; Tel.: +82-31-219-3531, Fax: +82-31-219-1613
[2] Department of Energy Systems Research, Ajou University, Suwon 16499, Korea

1. Introduction and Scope

In the field of electronics packaging, Pb-bearing solder alloys are mostly used as robust interconnecting materials. Such conventional interconnecting alloys are primarily composed of Pb and Sn with other minor alloying additions, which are widely used materials for the microjoining of electronic circuits and devices. Despite the reliable performance of Sn-Pb-based solders for interconnections, several European directives, such as the "Restriction of Hazardous Substances" (RoHS) and "Waste Electrical and Electronic Equipment" (WEEE), banned Pb and other toxic substances from the electronic interconnecting materials. As a consequence of these bans and regulation over the usage of Pb-bearing materials, the entire electronics packaging research community is in search of an alternative and sustainable replacement of Sn-Pb-based interconnected materials. Such issues have spurred the electronic industries to develop Pb-free interconnect materials. Therefore, it is essential for the research community to collaborate and explore sustainable alternatives for different interconnected materials for use in electronic packaging. In such case, the focus of the research must be placed on existing interconnection issues, such as ecofriendly, cost considerations, wetting, melting point, joint strength, corrosion, creep and thermomechanical fatigue, which will be useful in finding a suitable alternative to Pb-bearing solder alloys and interconnecting materials. In response to this challenge, progress in the synthesis, processing, and application of new emerging interconnection and solder materials is currently required in the microelectronic packaging research community. This Special Issue covers a wide scope in the research field of emerging interconnections and Pb-free solder alloys for microelectronic packaging.

2. Contributions

Five key research contributions (two research and three review articles) are published in this Special Issue of *Metals*. The subject matter of these pieces concern a wide range of microelectronic packaging disciplines, including (1) low-temperature and high-temperature solder alloys (Sn-Bi and Au-Ga), their processing and application, (2) nanocomposite solders, (3) brazing fillers for joining dissimilar materials, and (4) transient liquid phase (TLP) and wire bonding interconnection technologies for high-power electronics interconnections.

First, the two research articles discuss the effect of different additives on the microstructure and solder joint reliability. The first article by Tao et al. [1] demonstrates the solder joint reliability of Au-Ga solder for electronic devices working at high temperatures (300 °C) for aerospace exploration. The authors studied the effect of Cr in Au-Ga solder processed by smelting, casting, and hot rolling processes. The article presents comparisons of the wetting, oxidation resistance, and microstructures of the solder joint after aging at 300 °C for 240 h. The addition of Cr up to 0.3 wt% into the AuGa solder matrix improved the morphology, interfacial kinetics, and shear strength properties, which emphasizes the application potential of Au-Ga-Cr solder to high-temperature interconnections.

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The second article by Rajendran et al. [2] demonstrates the spontaneous modification of intermetallic compound (IMC) growth across a Sn-3.0Ag-0.5Cu/Cu solder joint, after adding ZrO_2 nanoparticles into the Sn-3.0Ag-0.5Cu solder matrix by mechanical mixing and melting methods. The authors conducted a comparative study on the effect of bimodal particle size distributions (5–15 nm and 70–90 nm) of ZrO_2 nanoparticles in the matrix on IMC growth and shear strength at 175 °C for 256 h. Their results indicated a decrease in the joint strength corresponding to the aging time, when thicker ZrO_2 particles (70–90 nm) was used. On the contrary, higher shear strength was obtained when finer ZrO_2 particles (5–15 nm) were used for solder joint tests. The difference in the IMC growth and shear strengths were attributed to the variations in the shape and size of Ag_3Sn IMCs dispersed in the solder matrix.

The next three articles provide a thorough review of the various emerging interconnection materials and technologies for microjoining applications, such as brazing fillers, low-temperature Sn-Bi solders, TLP bonding, and wire bonding technology for power electronics devices. Kang et al. [3] overview historical developments in low-melting-temperature solders, emphasizing Sn-Bi composition, in particular. The authors review the developments in Sn-Bi solders, the effects of nanoparticles incorporated into the Sn-Bi solder matrix on the morphology, shear strength, and wettability. Finally, the authors also highlight the developments in epoxy-reinforced Sn-Bi solders for emerging microelectronic packaging applications. This novel epoxy-embedded Sn-Bi solder is regarded as a no-clean solder, which is beneficial for reducing the amount of flux used in interconnections and electronic devices.

In another article, Kang et al. [4] present a comprehensive review of TLP and wire bonding technologies for high-temperature power electronics devices. The authors overviewed various bonding mechanisms, including solid-state diffusion bonding, TLP bonding, and dissimilar materials brazing for power modules. Ultrasonic wire bonding, ball bonding, crescent bonding, and wedge bonding technologies are also highlighted in their article. Finally, the authors detail the various reliability issues and provide guidance for future developments in this area. This review article presented a comprehensive review of potential bonding technologies over the decades, which can be used to improve the functionality of recent microelectronic packaging devices.

Finally, Ahn et al. [5] overview the developments in the field of microjoining fillers for various joining applications. This article demonstrates various developments in brazing technology, and details several brazing fillers developed in the past for metallic, as well as metal, to ceramic or ceramic to ceramic, joining. Several case studies for emerging areas in microjoining are also demonstrated in this article. Notable areas of interest highlighted in this article include the joining of nanostructures and multilayers, energy materials, automotive components, ceramics and nanocomposite brazing fillers. The authors also highlighted emerging high-entropy fillers for microjoining, which are a safe and provide a better alternative to multicomponent traditional solders and brazing fillers.

3. Conclusions and Outlook

This Special Issue covers comprehensive insights into the advancement of emerging interconnections and Pb-free interconnection material technologies. Evidently, there are still certain technology-related issues that need to be addressed in this context, and emerging interconnection technologies require further development. As a guest editor, I hope the articles of this Special Issue capture the interests of scientific and engineering research communities and proves to be useful for further research in this area.

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