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Pb-Free Glass Paste: A Metallization-Free Die-Attachment Solution for High-Temperature Application on Ceramic Substrates

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A lead-free glass frit paste as a die-attach material for high-temperature microelectronic application is proposed in this study. The glass paste containing Bi-based powder with a moderate amount of solvent was used for joining Si dice on ceramic substrates without any metallization preparation for either of the bonding surfaces. The die was bonded to a ceramic substrate at 430°C for 10 min. The study focuses on the mechanical and microstructural characterization of the joints with Si dice on two different types of ceramic substrate. Shear strength measurements were carried out at both ambient and 250°C to evaluate room- and high-temperature performance. Furthermore, the effect of aging at 300°C for 500 h on the mechanical properties is presented. The results of the mechanical and microstructural characterization demonstrate that low-temperature glass frit bonding is an effective die-attach method for harsh-environment electronic packaging.

Key words: Ruggedized electronics, die attach, glass paste high-temperature reliability, ceramic substrates

INTRODUCTION

Ruggedized (e.g., against coexistence of high temperature, corrosive medium, and mechanical stressing) electronics applications require a new form of technology to join the die to the substrate. Several European Union directives [e.g., Restriction of Hazardous Substance (RoHS) 2002/95/EC, End of Life Vehicle (ELV) and Waste Electrical Electronic Equipment (WEEE) 2002/96/EC], targeting to reduce and eventually remove lead from electronic devices, have been in effect since 2006.[1–3] High-temperature Pb-rich solder materials are included in the recast version of the RoHS Directive (known as RoHS 2 2011/65/EU), which was adopted by the European Council on 27 May 2011, but efforts to find Pb-free replacements for high-temperature application have met with very limited success so far.[4] One of the key reasons is that the reliability of solder is directly linked to its operating temperature. The homologous temperature (the ratio of the operating temperature to the melting temperature in Kelvin) should not exceed 0.8 since the mechanical properties of the joint degrade drastically beyond that point;[5] For instance, the melting point of a die attach should be more than 443°C to operate at 300°C. For the binary systems of Au-based alloys, most of the eutectic temperatures are less than 365°C (Au-Si: 363°C; Au-Ge: 356°C; Au-Sn: 280°C). Furthermore, current candidate solders such as Bi alloys, Zn alloys, and Au-based alloys have many

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