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Simplification of Low-Temperature Sintering Nanosilver for Power Electronics Packaging

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Conventional solders cannot meet the requirements for high-temperature applications. Recently, a low-temperature sintering technique involving a nanosilver paste has been developed for attaching semiconductor chips to substrates. Sintered nanosilver joints showed high reliability in high-temperature applications. We used the nanosilver paste to attach 10 mm × 10 mm chips by introducing a pressure as low as only 1 MPa during drying at 185°C. Die-shear tests showed that shear strengths of higher than 50 MPa could be generated by applying 5 MPa at 225°C for only 10 s or 1 MPa at 150°C for 600 s, followed by sintering for only 60 s at 275°C. The sintering temperature could be reduced to 250°C in most applications with a slight reduction in shear strength. As a result of good bonding, significant plastic flow and ductile fracture of the sheared silver joint could be observed by scanning electron microscopy (SEM). SEM also showed that the fracture of the sheared silver joint was a cohesive failure.

Key words: Nanosilver, sintering, pressure-assisted, electronic packaging, shear strength, microstructures

INTRODUCTION

Power electronics systems have wide industrial applications, ranging from inverters for hybrid electric vehicles to power converters in wind generators. Multichip modules consisting of large chips attached to substrates are some of the most important units in these power systems. Today, chips in such modules are bonded to the substrate by using conductive adhesives[1] or lead-free and high-lead solders by applying a solder reflow process at temperatures from 260°C to over 300°C to solidify the solder alloy.[2] However, there are many disadvantages of solder alloys, e.g., low electrical and thermal conductivity. In addition, soldered chip joints are susceptible to fatigue failure under cyclic loading due to creep and accumulation of inelastic strain.[3] Therefore, if the junction temperature is raised to 175°C, or even higher as envisioned for some future systems, the reliability of the soldered joint will become an even greater concern. In the quest for 175°C power modules,[4,5] the low melting temperature of solder attachments is one of the foremost challenges to overcome. The increased operating temperature approaches the melting point of conventional solders, making the joint susceptible to a host of thermomechanical and metallurgical problems.

The European power electronics industry is leading the way in introducing a superior lead-free die-attach technology to the marketplace.[6] Unlike the widely used soldering or adhesive bonding technologies,[1] this new technology, often referred to as low-temperature joining technology (LTJT),[7–12] is based on sintering of micrometer-sized silver powder at temperatures below 300°C. Usually, a screen- or stencil-printed layer of micron-scaled silver flakes is used as the interconnection material. To get such low sintering temperatures, pressure of

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