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Influence of Joining Conditions on Bonding Strength of Joints: Efficacy of Low-Temperature Bonding Using Cu Nanoparticle Paste

TOMOHIRO YAMAKAWA,[1,4] TADASHI TAKEMOTO,[1] MASAYOSHI SHIMODA,[1,2] HIROSHI NISHIKAWA,[1] KUNIO SHIOKAWA,[2] and NOBUTO TERADA[3]

1.—Joining and Welding Research Institute, Osaka University, Osaka 567-0047, Japan. 2.—Materials Engineering Research Department, Fuji Electric Co., Ltd., Tokyo 191-8502, Japan. 3.—Tukuba Research Laboratory, Harima Chemicals Inc., Tsukuba 300-2635, Japan. 4.—e-mail: yamakawa@jwri.osaka-u.ac.jp

We investigated a new low-temperature bonding process utilizing Cu nanoparticle paste without addition of sintering promoter. Joint bonding strengths above 30 MPa were achieved even at a low bonding temperature of 250°C. We attribute the higher bonding strengths of joints fabricated using the vacuum preheating process to the rapid progression of Cu nanoparticle sintering due to the activated nanoparticle surface at lower temperatures. The increase in bonding strength depended on the applied pressure, in addition to the bonding temperature. The formation of a dimple-like morphology was confirmed in the ductile fracture area. This indicated that the joint bonded strongly with the bonding layer, in agreement with the results of bonding tests carried out on strongly bonded joints. The bonding ability of the joints obtained using Cu nanoparticle paste could be improved by controlling the joint fabrication conditions.

Key words: Bonding, electronic device, joint process, nanoparticle, sintering, lead-free solder

INTRODUCTION

Assembled joints in power electronic devices are required to exhibit good reliability against thermal cycling and fatigue. The joints should especially be resistant to severe temperature cycling conditions. Although Pb-based solder has been used routinely to join Si chips to heat-spreading base materials made of copper,[1,2] the need to substitute Pb-based solder by Pb-free solder is increasing. Typical Sn-based Pb-free solders show lower melting temperatures and are less reliable than Pb-based solders.

In recent years, use of metallic nanoparticles as joining materials has received considerable attention. Although metallic nanoparticles exhibit low melting and sintering temperatures, after sintering, materials with properties similar to those of bulk metals and alloys are obtained.[3,4] Accordingly, metallic nanoparticles have been investigated as joining materials to replace high-temperature Pb-based solders. Until now, the bondability and reliability of joints fabricated with metallic nanoparticle pastes such as Ag,[5–9] Ag_2O,[10,11] and Ag-Cu compounds[12,13] have been reported. In particular, Ag nanoparticles facilitate sintering at lower temperatures when added to other metal nanoparticles. These metallic nanoparticles have often been prepared by wet chemical processes, which produce organic-layer-coated metallic nanoparticles.[14–16] The organic layer coating is usually removed by low-temperature heating, during which the metallic nanoparticles begin to sinter owing to their low-temperature melting characteristics caused by the nanosize effect. Ag nanoparticles, which are usually investigated for application in electronic packing

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