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Room-Temperature Nanoindentation Creep of Thermally Cycled Ultrasonically Bonded Heavy Aluminum Wires

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Recent findings suggest that creep occurs during thermal cycling of ultrasonically bonded wires, the extent of which is influenced by the nature of the temperature cycle, particularly its peak temperature. In this work, this hypothesis is investigated through a study of the power-law creep behavior of bonded 375-μm aluminum wires that have been thermally cycled. Data from a study of two wire purity levels (99.999% and 99.99%) and two different cycling profiles (-55°C to 125°C and -60°C to 170°C) are presented. Room-temperature creep stress exponents are derived for the wire bonds from constant-load nanoindentation tests and compared with their respective microstructures.

Key words: Ultrasonic wire bonding, thermal cycling, nanoindentation, creep, power electronics packaging

INTRODUCTION

Aluminum wire bonds which provide interconnections in power electronics packaging undergo thermomechanical fatigue during operation resulting from an accumulation of plastic strain. This buildup of damage eventually leads to failure by what is often referred to as bond "lift-off," examples of which have been cited in Refs. 1–3. These wires are usually ultrasonically bonded, a process which results in a highly heterogeneous and deformed microstructure[4–6] that is easily restored during subsequent thermomechanical service operating conditions. Significant microstructural changes including recovery, recrystallization, and grain growth can result.[7–9] Recent work has shown that these microstructural changes can offset the damage accumulated through thermomechanical fatigue.[10] In recent years, nanoindentation has emerged as a useful tool for the description of the dislocation glide plasticity of materials and can be used to gain insight into their high-stress, low-temperature creep behavior. Several recent studies have made use of room-temperature nanoindentation to characterize the creep behavior of the constituent intermetallic phases of electronic interconnect solder alloy joints.[11–13] The wire bond failure mechanism described above, though influenced by creep, may not necessarily be simulated or explained by room-temperature nanoindentation behavior per se. This is because the service operation of wire bonds is usually nonisothermal in nature and can involve high temperature excursions (in excess of 120°C, homologous temperatures $>0.4T_\mathrm{m}$ for aluminum). It would therefore more appropriately be described by diffusion-controlled creep mechanisms, which are more prominent under such conditions. However, it is virtually impossible to obtain specimens from the interface of a bonded wire for conventional uniaxial creep tests, which may better imitate the correct deformation regimes. The purpose of this work, therefore, is not to replicate the creep damage which occurs during service (believed to be influenced to a large extent by diffusion-controlled creep), but to test the hypothesis that significant creep takes place during thermal cycling, given sufficiently high peak temperatures. Along these lines, the intention is firstly to obtain a qualitative measure of postexposure

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