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Transient Crack Growth Behavior Under Cycle/Time-Dependent Step Loading for Pb-Containing and Pb-Free Solders

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In the present study, fatigue crack growth tests of Pb-containing [Sn-37Pb (wt.%)] and Pb-free [Sn-3.0Ag-0.5Cu (wt.%)] solders were performed under cycle/time-dependent step loading at a constant J-integral range (ΔJ). The C^* parameter was also estimated for discussing time-dependent crack growth behavior. The experimental results indicated that acceleration of the crack growth rate at the beginning of the second loading step was induced when the C^* value for the first loading step was high, regardless of time- or cycle-dependent crack growth and for both Sn-37Pb and Sn-3.0Ag-0.5Cu solders. The length of the acceleration region of the crack growth rate for both solders was in good agreement with the creep damage zone size estimated by the creep zone model proposed by Riedel and Rice.

Key words: Step loading, transient crack growth behavior, cycle dependent, time dependent, Pb-containing solder, Pb-free solder

INTRODUCTION

Solder joints serve as electrical connections and mechanical support as well as aiding heat dissipation for electronic packages. During the fabrication process and the service life, solder joints are usually subjected to cyclic loading due to mismatch of thermal expansion coefficient between the component and the board as well as due to mechanical vibration. Creep, fatigue, and their interaction are considered to be the main mechanisms leading to eventual failure of solder joints, while damage can be caused to solder joints by various mechanisms.[1] Generally, fatigue failure includes processes of crack initiation and growth. However, Solomon[2] reported that the total life of a solder joint is dominated by the crack growth process, since crack initiation usually occurs in the early stage of life. Therefore, it is important to understand the crack growth characteristics of solder materials, thus facilitating solder joint life assessment.

A number of investigations on the fatigue crack growth (FCG) behavior of solder materials have been reported; For example, Logsdon et al.[3] reported that the FCG behavior of Sn-37Pb* solder is controlled by creep–fatigue interaction, especially at low frequencies and high stress ratios. Similar FCG behavior of Sn-3.5Ag solder has been reported by Zhao et al.[4] Kanchanomai and Mutoh[5] and Tanaka[6] studied the effect of hold time on the FCG behavior of Sn-37Pb and Sn-3.0Ag-0.5Cu solders. Based on their results, the FCG behavior of both solders was dominantly time dependent (creep) under cyclic loading with longer hold time. Woo et al.[7] also reported that the FCG behavior of Sn-3.0Ag-0.5Cu solder under cyclic loading with low strain

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*The alloy compositions are in wt.%.