論文の内容の要旨

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Creep, fatigue and their interaction are considered to be the prevalent mechanism leading to the eventual solder joints fatigue. Although fatigue damage usually consists of crack nucleation and crack growth, crack growth process is dominant in determining the total fatigue life of a solder joint. Therefore, crack growth behavior of solder materials under interaction of creep and fatigue is necessary to clearly understand in order to developing the reliability assessment of SMT electronic packaging. The objective of the present work is to study the crack growth behavior under creep-fatigue interaction for Pb-containing (Sn-37Pb) and Pb-free (Sn-3.0Ag-0.5Cu) solders. Elastic-plastic fracture mechanic parameter, J-integral range (ΔJ) was used to discuss the crack growth behavior under cycle-dependent condition. While time-dependent fracture mechanic parameter, C^* was used to discuss the crack growth behavior under time-dependent (creep) condition.

Chapter 1: Introduction - A brief introduction on Pb-containing and Pb-free solder materials, their physical and electrical properties as well as their mechanical behavior have been outlined. The results of previous studies on crack growth behavior of Pb-containing and Pb-free solders have been reviewed to identify the important unsolved problems. The scope of the present work has been also presented.

Chapter 2: Effect of frequency and temperature on crack growth behavior of Pb-containing and Pb-free solders - The transition crack growth behavior of the both solders from cyclic- to time-dependent was investigated by decreasing the cyclic frequency from 10 Hz to 0.1 Hz and increasing the temperature from room temperature to 70℃. The experimental results showed that the crack growth behavior of the both solders tested under the higher frequency and lower temperature was predominantly cycle-dependent, while the crack growth behavior of both solders tested under the lower frequency and higher temperature was predominantly time-dependent. The transition temperature from cycle-dependent to time-dependent crack growth behavior was expressed as: $T(K)=30\ln f(Hz)+301$.

Chapter 3: Effect of hold time on crack growth behavior of Pb-containing and Pb-free solders - Solder joints are subjected to both static loading under normal operating condition (switch-on condition) and transient loading by power-on/off action. Therefore, cyclic loading with hold time would be one of the dominant fatigue loading modes for solder joints in electronic packaging. In Chapter 3, four types of loading waveform were adopted to investigate the effect of hold time on crack growth behavior of Sn-37Pb and Sn-3.0Ag-0.5Cu solders. The experimental results showed that the crack growth behavior of both solders tested under sinusoidal and triangular waveform without any hold time was predominantly cycle-dependent. While the crack growth behavior of both solders tested under trapezoidal waveform with hold times of 1, 5 and 10 s and triangular waveform with a hold time of 10 s was predominantly time-dependent. Under cycle-dependent condition the crack growth data were a function of ΔJ, while under time-dependent condition the crack growth data were not a function of ΔJ but rather of the C^* parameter.

Chapter 4: Transient crack growth behavior under variable cycle/time dependent conditions for Pb-containing and Pb-free solders - Crack growth behavior of the solder joints in the electronic packages would be changed from cycle- to time-dependent as well as from time- to cycle-dependent when their service conditions are changed. Therefore, in Chapter 4, fatigue crack growth (FCG) tests of Sn-37Pb and Sn-3.0Ag-0.5Cu solders were carried out by using six types of variable cycle/time dependent conditions under constant ΔJ loading. The experimental results indicated that acceleration of crack growth rate was induced when the C^* value for the prior loading condition was high regardless of time dependent or cycle dependent crack growth for both Sn-37Pb and Sn-3.0Ag-0.5Cu solders. The creep damage zone size of both the solders could be estimated by the creep zone size under assumption of creep zone definite by Riedel-Rice.

Chapter 5: Conclusion - The general conclusion and future prospects have been discussed and summarized.