Thermal Fatigue Crack Growth Characteristics of Underfill Resin

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1. Introduction

In recent years, miniaturization of electronic devices such as smartphones has been advanced. Along with this, IC packages are also required to be miniaturized. There are two problems with small IC packages: differences in coefficient of linear expansion and poor solder ball connection strength. In order to solve these issues, underfill resins are used. Underfill resins have the effect of improving the strength against thermal fatigue and mechanical fatigue. However, there is also a problem with underfill resin materials, which means that the failure of the underfill resin material causes the destruction of the entire IC package. From this, the purpose of this study is to develop a new thermal fatigue test using a Peltier element, and to clarify the thermal fatigue characteristics of the underfill resin materials.

2. Fatigue crack growth rate

In general, Paris law is used to predict the life of engineering materials. The Paris law is defined as,

$$da/dN = C(\Delta K)^m \tag{1}$$

However, Paris law is based on linear fracture mechanics and it is not suitable for underfill resin materials because they show visco-elastic behaviors. Therefore, the energy release rate is used instead of the stress intensity factor. The energy release rate is defined by equation (2).

$$G_{\mathrm{net}} = -\Delta U_{strain}/\Delta A \tag{2}$$

3. Finite element analyses

Finite element analysis was carried out to obtain the relation between energy release rate and crack length. Table 1 shows the equations obtained by the finite element analyses.

Table 1 the equations of energy release rate

UF-A	G=9828.2×(a/W)^3-1233.3×(a/W)^2+790.67×(a/W)
UF-B	G=4711.2×(a/W)^3-719.82×(a/W)^2+339.06×(a/W)

4. Experimental method

For the test, UF-A which is a general epoxy resin and UF-B which contains SiO_2 at 34 vol% in the epoxy resin was used. The thermal cycle temperature of the Peltier element was 0 to 80 ° C. During the test, the crack growth was observed with a microscope. The crack growth rate was calculated by image analyses. After experiments, the fractured surface was observed by SEM. Figure 1 shows the experimental apparatus.

Fig.1 Experimental apparatus

5. Results

The test results are shown in Fig. 2 and Table 2. The slope of UF-B is smaller than that of UF-A. This indicates that the inclusion of SiO_2 is an effective measure against thermal fatigue crack growth. Fig. 3 and 4 show the fractured surface of UF-A and UF-B. The striation was confirmed only on UF-A. UF-B has innumerable irregularities, which can be considered to be an obstacle to crack propagation.

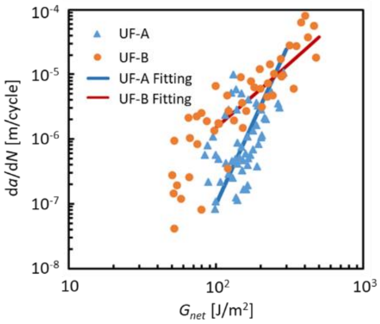
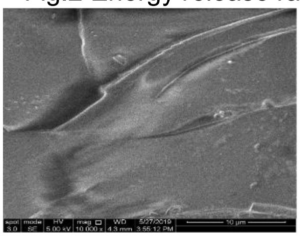


Fig.2 Energy release rate and crack growth rate



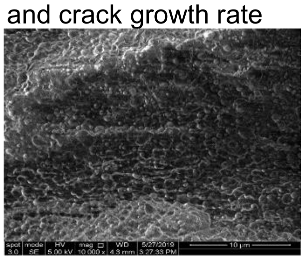


Fig.3 UF-A Fig.4 UF-B

6. Reference

[1] Omoto, Sato, Hamada, Noguchi, Examination of thermal fatigue crack growth evaluation method of epoxy resin composite, *the Japan Society Mechanical Engineers76*, (2010)113-114.