Microelectronics Reliability 91 (2018) 15–22

Contents lists available at ScienceDirect

Microelectronics Reliability

journal homepage: www.elsevier.com/locate/microrel

Adhesion strength of die attach film for thin electronic package at elevated temperature

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ARTICLE INFO

Keywords:
Adhesion strength
Elevated temperature
Loading rate
Single cantilever beam method
Viscoelasticity
Thin film
Die attach film

ABSTRACT

Adhesion strength of a thin film for electronic packaging was investigated. The effects of temperature and loading rate on the adhesion were observed considering the viscoelasticity of adhesive. Various temperature conditions over the glass transition temperature of the adhesive were applied with controlled loading rates. A small hot plate was specially designed to control the temperature. Loading rate was controlled by a servo motor. A cantilever specimen was fabricated by two rectangular silicon chips. The adhesion was measured by a modified single cantilever beam method. Bending force was applied to the cantilever using rotatable jig. Adhesion strength was found to strongly depend on the temperature and loading rate. Below the glass transition temperature (T_g), the adhesion strength was increased with increasing loading rate. Near the Tg, the adhesion strength was decreased with increasing loading rate. Above the T_g, the adhesion strength did not significantly depend on the loading rate.

1. Introduction

Die attaching adhesive is an essential material for electronic packaging. The adhesive is usually polymer-based adhesive and it is applied in a liquid or film form. The film type adhesive has following advantages compared to the liquid type adhesive; packaging process is simple, there is no resin bleeding after die attaching, and it is easy to control the thickness of adhesion layer. Therefore, the film type die attach adhesive has been used extensively for electronic packaging and it is known as die attach film (DAF) [1].

In a package, delamination at the DAF has been a crucial failure mode. If any external driving force exceeds a critical adhesion at the interface, the delamination occurs and results in failure of the package, in which the typical external forces are thermo-mechanical loading, mechanical loading, hygro-swelling, and so on. In general, such external forces are difficult to be controlled. Therefore, increasing of adhesion is a better method to achieve reliability of a package. The adhesion of DAF strongly depends on temperature, loading rate, moisture absorption, and so on [2, 3]. Therefore, it is very important to measure the adhesion as a function of such independent variables. One of the most important parameter is temperature. A sufficient adhesion strength should be sustained at high temperature. For example, one critical temperature of a package is about 260 °C which is a peak temperature of reflow process.

There are many test method to measure the adhesion. Peel test method is a simple method to measure the adhesion of flexible film wherein the film itself is loaded at 90° or at a specific angle [4]. Shear mode (Mode II) test is commonly used when the adhesive bonds two solid adherends such as silicon chip. Shear force is applied and adhesion strength is evaluated by detecting maximum applied force. Die shear test is a typical method to measure the adhesion of DAF in shear mode [5]. Tensile mode (Mode I) test is more difficult compared to the shear mode test. It is relatively difficult to prepare test sample. And the test needs more complicated test equipment. Stud pull test is a direct application of tensile mode [6]. Double cantilever beam (DCB) method is a well-developed technology to measure the tensile mode adhesion [7, 8]. However, it needs special process to make a specimen and needs hot chamber to be performed at high temperature [9].

Single cantilever beam method (SCB) is a branch of DCB, which uses only one cantilever [10–12]. Recently, a modified SCB method applied to electronic packaging had been announced [13]. They used a specially designed jig. A silicon chip itself became a cantilever without attaching any extra component. Their test method was simple and the specimen could be fabricated by following the same manufacturing process of commercial packaging product. And any unintended condition during the specimen preparation could be excluded. Through this method, adhesion of a die attach film was successfully measured in tensile mode. However, they showed the test results only at room temperature.

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https://doi.org/10.1016/j.microrel.2018.07.143
Received 4 January 2018; Received in revised form 10 June 2018; Accepted 24 July 2018

Adhesion at high temperature was not considered.

Polymeric adhesive materials are very sensitive to temperature and shows viscous behavior [14]. There are large differences in mechanical properties before and after the glass transition temperature (T_g). In addition, it shows a strong dependency on strain rate [15–17]. Therefore, it needs modified fracture parameters such as 'energy release rate' or '*J*-integral' to the temperature-dependent polymeric adhesive materials. Hence, the J_v-integral considering the viscoelasticity of the material had been proposed and several studies have been conducted accordingly [18, 19]. Note that this parameter can be considered only below T_g [20]. When the temperature exceeds T_g, a quantitative parameter is reasonable and can be defined by the adhesion strength.

In this study, we aim to develop a technique of evaluating the adhesion strength of a film adhesive for semiconductor packages in elevated temperature exceeding T_g. Test machine was developed and adhesion strength was measured.

2. Test specimens and material properties of film adhesive

A die attach film (DAF) for electronic packaging is investigated in this study. It is usually used to attach a silicon chip to printed circuit board or another chip for stacking. The thickness of the film was 10 μm. The test specimen was fabricated using well developed commercial packaging processes. A sheet of adhesive was attached to the bottom of a silicon wafer (diameter of 300 mm, and thickness of 550 μm). The wafer along with the attached adhesive was sawn into small chips of dimensions 9.6 × 15.2 mm^2. The two separated chips were stacked in the form of a cantilever structure as shown in the left schematic of Fig. 1. The stacked specimen was flipped upside down, and then attached to the mounting block as shown in right schematic of Fig. 1.

As described in Fig. 1, the active layer of the chip is down side of the cantilever in the figure and backside of chip is upper side because the specimen is flipped. The overhang of the chip becomes a single cantilever beam (plate) when the jig pushes the edge of the overhang. By the upward motion of the jig, the crack propagates between the film adhesive and upper chip (plate). This single cantilever beam (SCB) method is applied in this study. No extra layer at the interface exists to make any initial crack. The stress concentration at the intersection points of the two chips induces the crack initiation. The adhesive on the upper plate can be neglected because its stiffness and thickness are considerably smaller than those of the silicon chip. The detailed description of the single cantilever beam method can be found in the reference [21].

The material properties of the film adhesive were measured using a dynamic material analyzer (DMA) test machine by adhering to the ASTM D4065 standard. The size of the specimen was 5.5 × 21.0 × 0.7 mm^3. The test was performed in a multiple frequency mode (0.33, 1.0, 1.33, and 10.0 Hz) in the temperature range from −45 °C to 140 °C. Fig. 2 shows the measured storage modulus, loss modulus, and tangent delta of the film adhesive. It is shown that the glass transition temperature (T_g) is approximately 45 °C. The elastic modulus before and after T_g at the frequency of 1.0 Hz are approximately 1.0 GPa and 15.0 MPa, respectively.

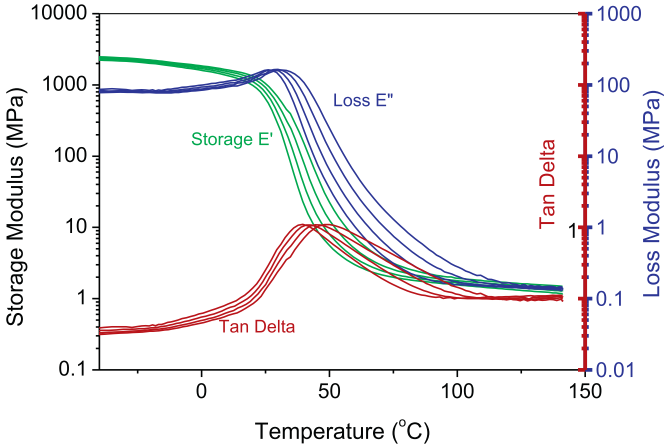

Fig. 2. Viscoelastic properties of film adhesive. Loss modulus, storage modulus and tangent delta.

3. Heating system

The heating system and specimen mounting fixture were specially designed as shown in Fig. 3. This system was appropriate for a small specimen studied in this study. For heating, a Kapton film heater (Omega Co.) was used. The allowable heating temperature of the film was 120 °C, which was suitable for this study and could be controlled easily. The heating area of the film was 18 mm × 40 mm. The film heater was attached to an iron substrate of thickness 2.0 mm. And the substrate was mounted on the insulation block made of a glass fiber composite of high stiffness and low thermal conductivity. The appropriate contact force between the mounting block and heater was achieved by restitution force of soft sponge attached to the bottom of insulation block. Such heating film, steel substrate, insulation block, and soft sponge consisted a heating part. And the heating part could be easily combined or removed through the space between the supporting legs.

Fig. 4 shows a specimen attached onto the mounting block and

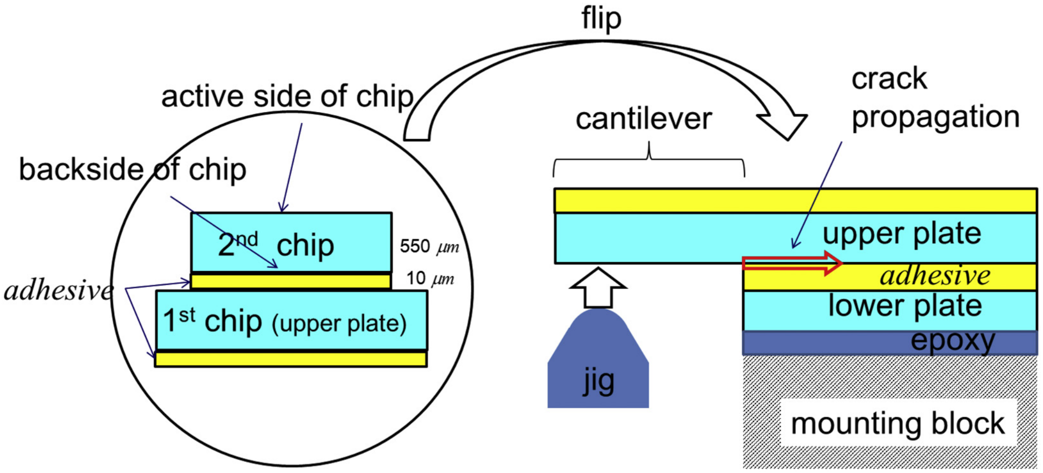

Fig. 1. Schematics of specimen and single cantilever beam method.