Combinatorial Approaches for Characterizing Thin Film Bond Strength

Martin Y.M. Chiang, Daisuke Kawaguchi, Christopher M. Stafford

Polymers Division, National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899

INTRODUCTION

One area of concern for both customers and manufacturers in the use of thin films is the reliability of the bond strength between film and substrate. For example, the next generation of electronic components will require novel thin films to be integrated into their construction. In developing these new materials, it is important to assess the reliability of the bond strength in a fast, practical and reproducible fashion. The objective of this study is to develop a combinatorial or multivariant approach based on edge delamination [1] to investigate the bond strength between a thin film and a substrate. This technique is expected to provide information about the interfacial integrity, quantify the bond strength and increase the rate of material innovations [2,3].

In our proposed combinatorial edge delamination test, a film is coated onto a relatively rigid substrate in such a way that the film has a thickness gradient in one direction (Fig. 1a). The film is cut into a square grid pattern to form an array of individual edge delamination samples on the substrate (Fig. 1b). The cut penetrates some distance into the substrate also. The edges are at 90^o to the interface of the film/substrate. To introduce a loading, the specimen is cooled with a temperature gradient applied in the direction orthogonal to the thickness gradient (Fig. 1a). Debonding events will be observed for those samples having critical stresses that depend on the combination of local temperature and film thickness. Consequently, a failure map as a function of temperature and film thickness can be constructed with one specimen in a single step, as shown in Fig. 1a. Also, the bond strength of a film to a substrate can be deduced from this failure map as long as the thermo-mechanical property (the stress-temperature relationship) of the film to the substrate is well characterized.

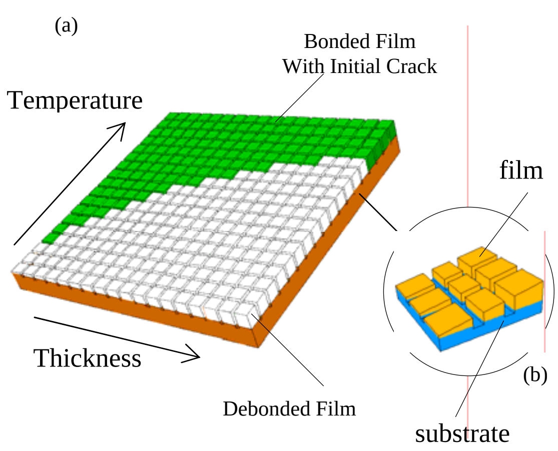

Fig. 1 A schematic of the combinatorial approach to the edge lift-delamination test: the multivariant specimen with film thickness and temperature gradients, and final failure map (a); a square pattern array of individual edge delamination samples on the substrate (b).

RESULTS and DISCUSSION

We prepared three combinatorial edge-delamination specimens using borosilicate glass as the substrate, and a commercial epoxy as the film. In the combinatorial test, a single specimen of an epoxy film bonded to a glass substrate with a thickness gradient was subdivided into separate edge-delamination samples. The thickness gradient of the film for the specimens was kept in (4.75 ± 0.05) mm/mm. The thickness varied from 90 μm to 260 μm (the standard uncertainty is 5 μm). The temperature gradient for the specimen was from -105 °C to -80 °C (the standard uncertainty is 2 °C). After applying the load (temperature gradient), debonding for those edge-delamination samples (on the combinatorial specimen) having critical stresses can be observed by eye (Fig. 2a). Also a failure map of the epoxy/glass bond as a function of both temperature and film thickness was extracted from the test result (Fig. 2b).

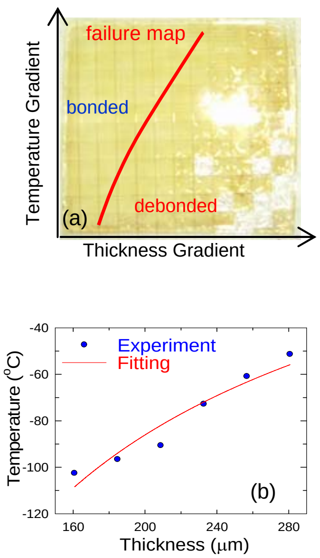

Fig. 2 A typical experimental result of the combinatorial edge-delamination test (a), a failure map is extracted from the result as a function of temperature and epoxy film thickness.

In this epoxy/glass system, all the failures observed were cohesive fractures of glass. Based on the stress-temperature relationship of the epoxy/glass system, the fracture toughness of the glass was deduced from the failure map of each combinatorial specimen (Table 1). The mean value of the fracture toughness from the results listed in the table is 0.85 $MPa \cdot m^{1/2}$ (the standard uncertainty is 0.07 $MPa \cdot m^{1/2}$), which is in line with the reported value of 0.80 $MPa \cdot m^{1/2}$ [4]. The results in this study clearly indicate that the proposed combinatorial edge delamination test can be used to predict the reliability of bond joint as a function of film thickness and temperature and quantify the bond strength in a fast and accurate manner.

Table 1 Fracture toughness extracted from failure maps of three combinatorial edge delamination tests

Combinatorial Specimen Number	Fracture Toughness ($MPa.m^{1/2}$)
1	0.91
2	0.77
3	0.88

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