Determination of interface cohesive zone parameters of a mixed mode cohesive law by in-situ delamination experiments

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Mechanics of Materials

Problem definition

High density integration (Fig. 1a) \(\Rightarrow\) Interface delamination (Fig. 1b)

Fig. 1 (a). Cross section of a typical micro-electronic package (b). Scanning acoustic image of a delaminated package. Red areas indicate delaminated regions.

Cohesive zone (CZ) approach is often used to describe the interface behavior in finite element (FE) predictive models to minimize delamination failures (Fig. 2).

Fig. 2 Cohesive zone laws are used to describe the constitutive behavior of the interface in FE models. Experimental determination of all the interface CZ parameters of a mixed mode cohesive law is an ongoing challenge.

Goal:

Present an approach for determination of mixed mode interface CZ parameters \((\phi_n, \phi_t, T_{n,max} \text{ (or } \delta_n), \text{ and } T_{t,max} \text{ (or } \delta_t))\).

Experimental setup

A miniature mixed mode bending (MMMB) setup (Fig. 3) capable of carrying out in-situ tests on miniature structures for characterization of delamination was successfully developed [1] and applied in the current study.

Fig. 3 (a,b,c) the MMMB setup mounted in micro-tensile stage showing various parts. (d) Setup in SEM chamber.

Methodology - Results

Mode I parameter identification:

From in-situ mode I delamination tests, important local information such as elongation of the interface layer at the crack tip \((\Delta_{n,exp})\), and the rotation \((\theta)\) of the loading points during crack initiation were captured using digital image correlation (DIC) (Fig. 4a,b).

Fig. 4 (a) Local displacement field data captured with DIC. (b) schematic diagram explaining the required local data for the measurement of mode I traction-separation law plotted in (c).

This information was used in combination with the measured applied global Force \((F)\) and the sample width \((B)\) to calculate the full mode I interface traction-separation law (Fig. 4c) using the approach proposed by Andersson et al. [2].

Mode II parameter identification:

Critical energy release rate (CERR) was determined as a function of mode angle \((\psi)\) from the delamination tests performed over the full range of mode mixities (Fig. 5). Resultant data was fitted with the work of separation \(\omega_{tot}(\psi)\) as a function of mode angle given by,

\[
\omega_{tot}(\psi) = \int_{0}^{\infty} T_n(\Delta_n, \Delta_t) d\Delta_n + \int_{0}^{\infty} T_t(\Delta_n, \Delta_t) d\Delta_t, \quad (1)
\]

to find the optimum value of \(\gamma \left(= \frac{T_{t,max}}{T_{n,max}}\right)\) for any assumed CZ law representing the interface of interest.

Fig. 5 Experimental CERR-mode angle data fitted with \(\omega_{tot}(\psi)\).

Conclusion

An experimental approach for the determination of all cohesive parameters of a mixed mode CZ law is presented.

References: