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Introduction

In the electronics industry, reliability of the IC package is usually assessed by the integrity of its solder joint interconnects. The latter have the function of forming both electrical and mechanical connections between the silicon chip and the printed circuit board. Repeated switching of the electronic device leads to fatigue damage of the solder joints. Progressive damage will eventually result in a device failure.

Objective

The objective of this research is to model the fatigue damage process in a solder bump when subjected to cyclic loading. The model should describe the gradual degradation of the solder bump material and predict its life-time.

Methodology

The solder bump shown in Figure 1 is modeled in plain strain. Cyclic loading is applied in terms of sinusoidal shear displacement which is prescribed incrementally. Cohesive zones are embedded at physical boundaries in the solder material, i.e. grain boundaries and interphase boundaries. In a first step, the material is idealized as a well-defined two-phase system (Figure 1).

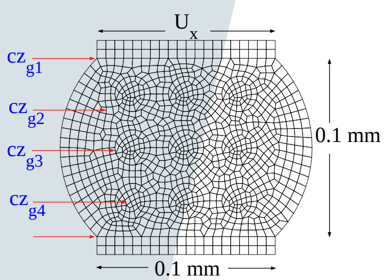

Figure 1: Modeled geometry.

A cohesive zone is a four-noded element (Figure 2) with zero initial thickness ($\mathbf{\Delta} = 0$). Its constitutive behavior is specified through a relation between the separation Δ_α and a corresponding traction T_α, with α being either the local normal (n) or tangential (t) direction in the cohesive zone plane.

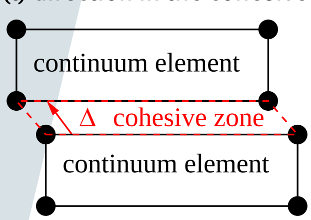

Figure 2: Illustration of the cohesive zone.

A damage variable D_α is incorporated into the cohesive zone law to account for the gradual loss of stiffness [1]. The variable varies between (0) for damage-free cohesive zones and (1) for completely damaged zones. The rate of damage is taken to be proportional to the rate of separation and the current damage, i.e. $\dot{D}_\alpha \propto \dot{\Delta}_\alpha(1 - D_\alpha)$.

Results

Figure 3 shows the distribution of damage at different cycles. It is clear that damage starts at the interfaces with the second phase particles, as these were initially assigned the lowest stiffness. Later on, damage propagates to the upper and lower interfaces, then throughout the bump.

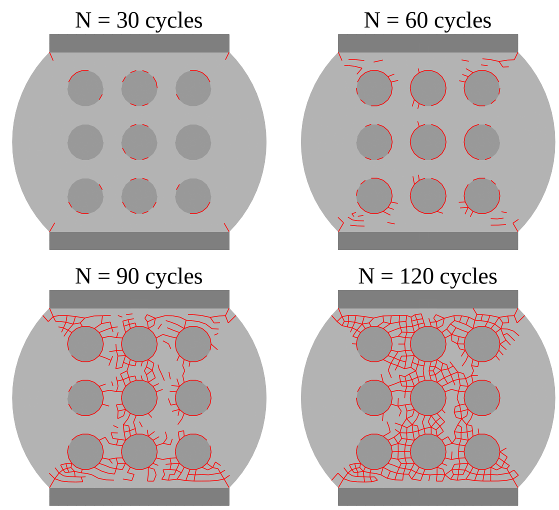

Figure 3: Damage distribution in the solder bump after different loading cycles. Red lines indicate damaged cohesive zones.

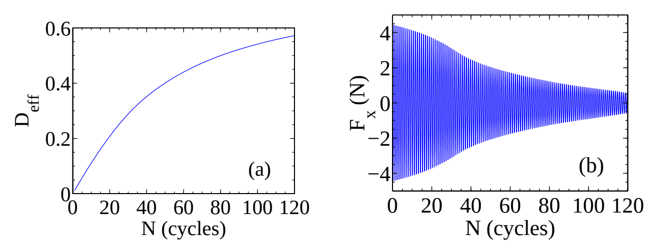

Figure 4: The total damage in the solder bump (a) and the reaction force (b) versus the number of cycles.

The evolution of damage in the solder bump with the number of cycles is shown in Figure 4(a), where D_{eff} is an average effective measure of damage in the entire bump. The reaction force shown in Figure 4(b) decreases as a result of the gradual loss of the overall stiffness of the bump.

Conclusions

The cohesive zone approach seems promising in modeling fatigue damage. For a quantitative comparison with experimental observations, a proper choice of cohesive and other parameters in the model is required.

References:

[1] Roe, K.L. and Siegmund, T., 2003. *An irreversible cohesive zone model for interface fatigue crack growth simulation. Engineering Fracture Mechanics* **70**, *209–232.*

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