Delamination in IC stacked back-end structure

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Delamination in IC stacked back-end structure

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Introduction

The evolving process of miniaturizing integrated circuits (ICs) requires the introduction of new materials. These new materials have altered mechanical properties. Due to both the reduced physical dimensions and the application of new materials, the thermo-mechanical reliability of ICs becomes an important design issue.

Figure 1 shows a typical IC package. The actual IC, depicted in figure 2, consists of

- the silicon substrate,
- the front-end containing thousands of transistors and
- the stacked back-end structure of metal lines, which connect the transistors.

If the IC is not carefully designed, cracks occur under thermo-mechanical loading, which results in IC failure. Simulation tools can assist the IC engineer to 'design for reliability'.

Objective

The objective of this research is to implement advanced damage models in simulation tools. It focuses on delamination in the stacked back-end structure, because this is an important failure mode.
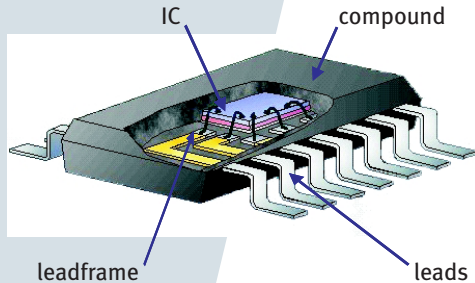
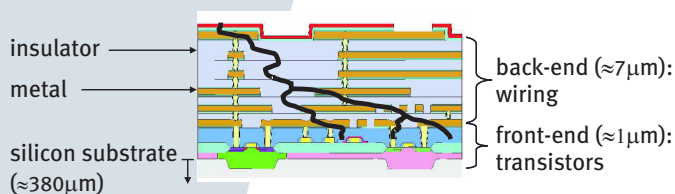

Figure 1 *Typical IC package.*

Figure 2 *IC layout.*

Methods

Multi-scale modelling

The finite element method (FEM) forms the basis for the simulation tools. However, it is not applicable in its usual form due to large scale differences. Therefore, a multi-scale approach will be adopted as shown in figure 3. A global model predicts the macroscopic thermo-mechanical behaviour, whereas a local model predicts the microscopic failure behaviour.

Two candidate multi-scale approaches will be considered.

- Computational homogenization [1]:
  The global model does not use an explicit constitutive law, but the stress/deformation relation follows from computations on the microscopic level using representative volume elements defined for discrete material points.
- Global/local approach:
  The global model uses an equivalent constitutive law, for which the parameters are modified adaptively based on the analyses of local models of small regions.
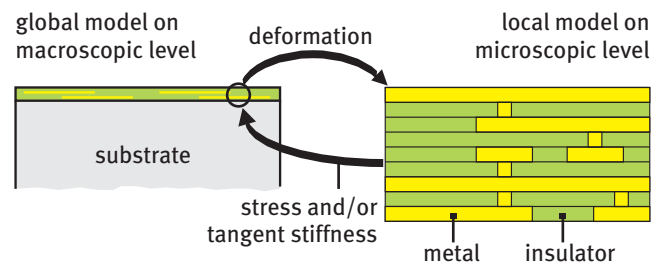

Figure 3 *Multi-scale approach.*

Cohesive zone modelling

The cohesive zone model (CZM) of Xu and Needleman [2] is incorporated on the microscopic level to predict failure due to delamination of the stacked back-end structure. This model describes the relation between the separation Δ at the interface of interest and the required traction T. Figure 4 shows the typical constitutive behaviour for this type of models.
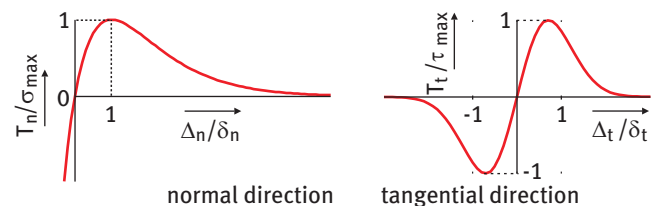

Figure 4 *CZM behaviour in dimensionless quantities.*

Challenge

The challenge of this research is to develop a methodology for the damage transition from the microscopic level towards the macroscopic level.

Conclusions

This recently initiated research project will provide the IC engineer with a simulation tool for the fast and reliable evaluation of different design alternatives in order to obtain a thermo-mechanically reliable IC.

References:

[1] KOUZNETSOVA, V.: *Computational homogenization for multi-scale analysis of multi-phase materials* (Ph.D. thesis, TU/e, 2002)

[2] XU, X., NEEDLEMAN, A.: *Numerical simulation of fast crack growth in brittle solids* (J. Mech. Physics of Solids 42, 1994)