FRACTURE ELECTRONICS - FRACTURE ANALYSIS OF MICRO-ELECTRONIC COMPONENTS AND CHIPS

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Various methods of microdeformation analysis (e.g. micro moiré and microDAC, laser field measurement technique, acousto-microscopy, X-ray stress analysis) are coupled with FEM simulation to characterize the local thermo-mechanical behaviour of microsystems e.g. chipcards, printed circuit boards and micro-sensor components. Creep crack and thermal fatigue crack behaviour in microcomponents have been studied in detail.

GENERAL REMARKS

The present state of the art of thermo-mechanical reliability analysis of microcomponents in microelectronic systems requires modern fracture analysis to describe more precisely the real life-time of microsystems.

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With growing miniaturization the "local" material properties and local temperature gradients exert a greater influence on the functionality and the reliability of microsystems than in any macroscopic components. Various kinds of inhomogeneities, localized stresses and the related phenomena of thermal "misfit" effects have to be taken into account. The term "Fracture Electronics" has been increasingly used as a working term recently to characterize the application of advanced fracture analysis in the field of microelectronics and microsystem technology. The chip size has become larger within the last years and it will become considerably larger in the near future too. From this it already follows that the deformation and crack phenomena of chips and of chip packages will become increasingly important though the whole microsystem will become smaller. The example of fracture phenomena of chips in so-called smart cards (e.g. telephone cards) is characteristic for the complicated mechanisms of crack progress in microcomponents. Finite element calculations of the components are coupled with testing techniques based upon laser microscopy and other laser field measuring techniques (e.g. holographic interferometry, speckle photography, speckle interferometry), laser scanning microscopy, acoustic microscopy, and the so-called microDAC method via digital image processing units. The microDAC method (DAC - Deformation Analysis by Means of Correlation method) has been applied to obtain the local displacement field in a microcomponent in a special procedure which is similar to laser optical interferometric deformation analysis. The experimental data were used as direct input quantities for the quantitative evaluation of crack and fracture behaviour of the micro component, e.g. the smart card, the chip and others. The quantitative crack evaluation in solder bumps of flip chip packages in microsystems is an unsolved problem until now. The authors have applied the microDAC analysis to this complicated problem in combination with finite element analysis.

The comprehensive analysis requires also an adaptive finite element meshing of the crack and damage region. This provides the basis for a suitable reliability evaluation of the microcomponents based both on the in-situ experiments and the FE-analysis.

FRACTURE CRITERIA APPLIED TO ADVANCED ELECTRONIC PACKAGING MATERIALS

An electronic package usually consists of a variety of different materials. Within the interconnected regions one can find metallic materials (e.g. metallization layers, soldering materials), ceramics, plastic and composite materials of different kind. The mechanical and thermal reliability analysis for this reason cannot be as simple as in most macroscopic applications, where large parts of the material usually can be assumed to be homogeneous. Due to the global as well as local misfit effects within the packaging areas we find different kinds of nonlinearities concerned with local plasticity, creep and fatigue phenomena related also to the thermal effects. A precise analysis of the local stress, strain and temperature fields taking into account nonlinearities and inhomogeneities in the micro material behaviour is a good basis for advanced fracture concepts. The latter take also into consideration thermal effects as well as creep phenomena, mainly found within and around the interconnected regions (e.g. solder regions). Local and global temperature gradients and heat dissipation have to be taken into account in fracture concepts in many microelectronics applications. That is why Fracture Electronics has to be a nonlinear coupled field concept from the basic understanding. In many practical applications, however, linearized approximations neglecting the field coupling terms may already lead to good results as it is the case with the known concepts of linear fracture mechanics applied to normal fracture applications on the macroscopic scale.

Because of the field coupling and the nonlinearities of fracture phenomena in electronic applications the so-called generalized integral fracture concepts seem to be very well suited to describe the applications in the field of fracture electronics. The local heat dissipation effects are of principle importance for most of the fracture electronics applications. The JT_J-concept is an example for such a "dissipative" criterion. It is directly related to nonlinear crack-resistance (J-R) curves and finally also leads to advanced failure assessment diagrams directly applicable to packaging problems.

EXPERIMENTAL CRACK ANALYSIS OF ELECTRONIC PACKAGES

It is difficult to include local structures as well as the real geometry of packaging components into design tools (e.g. FE codes). Therefore, a special software tool was developed to generate FE-meshes in overlay technique directly from metallographic or laser scanning video pictures. These "initial" FE grids can be further processed by means of special (adaptive) mesh refinement methods. The failure regions near a crack-defected region or an interfacial crack tip as a rule have microscopical dimensions. Field measurements combined with image processing and coupled with FE simulation have become a powerful tool for the microcrack evaluation in microelectronic components.

A very new speciality in local quantitative micro deformation analysis is the so-called microDAC method. This technique starts with a SEM micrograph of the crack tip region. A SEM micrograph is an electronically lensless generated image of the detected local signal intensity distribution, released by the primary electron probe inside the scanned specimen surface cut out. The microDAC uses the grey level distribution of the digital SEM micrograph that represents the registered signal intensity for a given object structure of a microspecimen or any microcomponent. The displacement vector of any point in the image of a given load level (object map) relating to its position of another one (reference map) is determined using a special surrounding pixel window. Its dimension depends on the grey level distribution inside the window that has to be characteristic just for this one point. Now inside the frame of a larger surch window in the object map this reference map pixel window is superimposed and displaced pixel by pixel. Then, on every position the correlation coefficient has to be calculated and stored in a data matrix. The real displacement is obtained in case the correlation coefficient takes its maximum value. The microDAC method has been applied by the authors to describe the thermo-mechanical behaviours of solder bumps in micro solder bumps produced by flip chip packaging technology. Fig. 1 shows the typical result obtained by microDAC. The method was also applied to cracks at pins (see Fig. 2) and in components of PCB.

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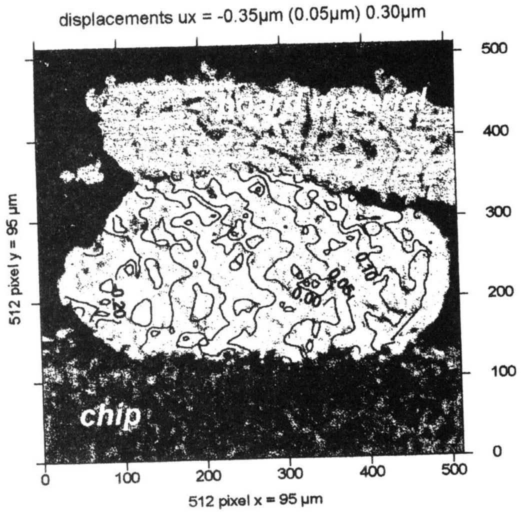

Figure 1. Thermal Deformation of a Microcrack at a Gold Ball Microbump

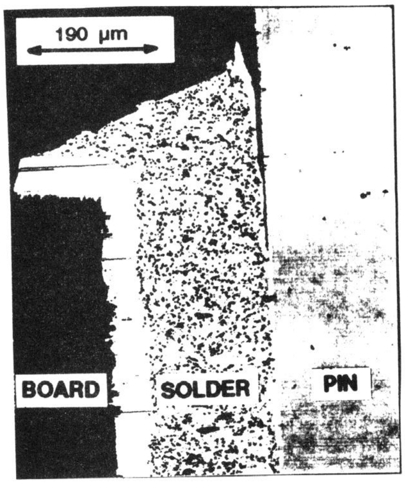

Figure 2. Microcrack at the pin-solder interface on a printed circuit board