4.5.1. VISUALIZATION OF PACKAGE INDUCED DEFORMATION OF INTEGRATED CIRCUITS

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Microelectronics makes live easier and safer. In modern automobiles micro electronic power devices are used increasingly to control the engine of the car and elevate the safety and comfort of its driver. But the increasing implementation of car electronics makes the vehicle also vulnerable to microelectronics failure. During his life a car is usually subjected to all kinds of environmental changes like differences in temperature and humidity or mechanical stress, therefore, electronic components need to have a reasonable robustness in order to match the longevity car.

A major reason for microelectronics failure is due to the way these components are fabricated: Within a microelectronic component containing an integrated circuit (IC) the interconnect structures establish a link between switching entities of the silicon chip and the component's outer pins designated to become soldered to a printed circuit board (PCB). The mechanical interaction between package and chip induces deformations which may become starting points of mechanical flaws [1–3], and hence bears the risk of passivation cracking over the metal lines and therefore the failure of the device because of corrosion. The knowledge of the real deformation of the chip is essential for calculations and predictions concerning nano fracture mechanics and hence to develop a device package with minimized IC deformation.

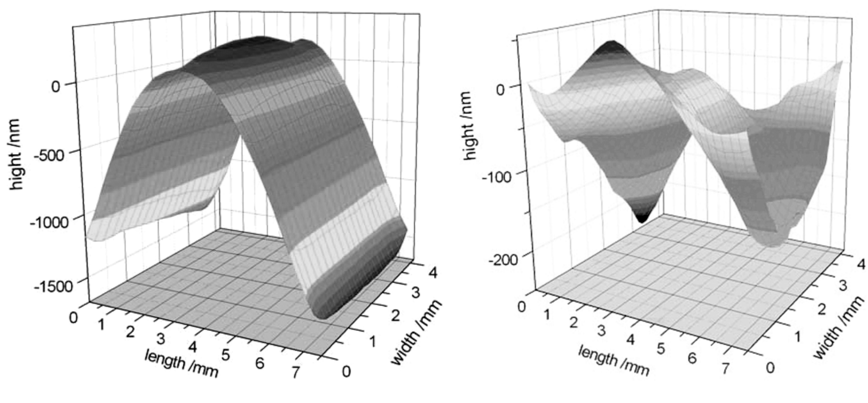

Fig. 1. 3D surface profiles (lateral resolution: 14.4 µm × 14.4 µm, height resolution: ±1 nm) deduced from SLCR inspection. Left: chip just after packaging; right: chip after a stress treatment of 1000 temperature cycles from −55 to +150°C

To visualize the real deformation of the chip (the thin Silicon crystal) we developed a new inspection method at the materials research beamline (BAMline) [4] at the Berliner Synchrotron Radiation Source BESSY. The method – **S**ynchrotron **L**aue **C**ontrast **R**adiography (**SLCR**) – is based on the coherent scattering of monochromatic synchrotron radiation by the net planes of the silicon single crystal of the electronic device. To explore the final shape of the whole chip the microelectronic device is placed in front of a CCD camera system (pixel size 14.4 μm × 14.4 μm) and irradiated by a parallel and monochromatic beam (55 keV). The surface normal of the chip is parallel to the beam axis and the beam cross section covers the entire chip. The measurement is performed by rotating the device around an axis perpendicular to the beam while recording in parallel the radiographs of the device. For specific orientations of the device dark bands across the silicon crystal become visible. They are moving across the radiograph correlated to the rotation and the deformation of the crystal. Doing so a series of dark band positions (isoclines) across the whole crystal is assembled (aggregated) in a 2D plot. The isoclines density represents the local radius of curvature of the crystal, typically, ranging between 5 m and 50 m (the higher the density the smaller the radius of curvature). From the 2D isoclines plot a 3D surface profile of the flexural loaded Silicon crystal is derived (see fig. 1) with a very high resolution of about ±1 nm in height. A 3D surface profile of a chip just after packaging and after a stress treatment of 1000 temperature cycles from −55 °C to +150 °C was measured. The crystal surface has changed from a smooth convex shape to a more irregularly profile (like a magic carpet). This is explained by a partial loss of the adhesive strength between the package and the chip caused by degradation e.g. of the solder during stress treatment.

The SLCR measurement also discovers the mechanical effect of the gold wire bonds and lead solder voids on the surface of the silicon crystal. Finally, even higher order effects such as interaction between void and bonding wires have been detected. From these results SLCR can be considered as a new powerful inspection method to evaluate even minute degradation processes in electronic devices. This is an essential for any prognostic reliability work in the future.

References:

1. **Alpern P.** et al., IEEE Trans. CPMT A17(3), 583 (1994); Erratum in 18, 862 (1995).
2. **Alpern P.** et al., VTE 10(1), 10 (1998).
3. **Suo Z.** Comprehensive Structural Integrity (Milne I., Ritchie R.O., Karihaloo B., Editors-in-Chief), Elsevier 2003.
4. **Müller B.R.** et al., Nucl. Inst. and Meth. in Phys. Res. A, 467/468, 703 (2001).