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Extension of fracture mechanics to small dimensions – Microcrack evolutionand failure in 3D structured materials

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Fracture mechanical properties of materials in micro- and nanoscale dimensions have become an important area of fundamental research, including the development and introduction of new techniques for micro- and nanomechanical testing. At the same time, there is an increasing need of industry to evaluate the risk of microcrack evolution at small length scales that can cause catastrophic failure in 3D-structured systems and materials such as leading-edge integrated circuits, advanced battery electrodes and composites.

The combination of miniaturized mechanical tests with high-resolution imaging enables a precise control and monitoring of force and displacements in materials at the micro- and nanoscale. *In-situ* mechanical tests of 3D-structured systems and materials applying a micro double cantilever beam (micro-DCB) test in alaboratory X-ray microscope provide a unique capability for high-resolution 3D imaging of microcrack evolution while a force is applied. Nano X-ray computed tomography (nano-XCT) is used to image microcracks in integrated circuits with sub-100nm resolution and to draw conclusions for the robustness of microchips. A novel methodology for the determination of the local critical energy release rate G_c in 3D-patterned systems will be explained, and the ability of a controlled steering of microcracks into regions with high fracture toughness will be demonstrated.

The combination of micromechanical testing and high-resolution X-ray imaging opens the way for the development of design concepts for novel engineered materials systems based on their local mechanical properties.