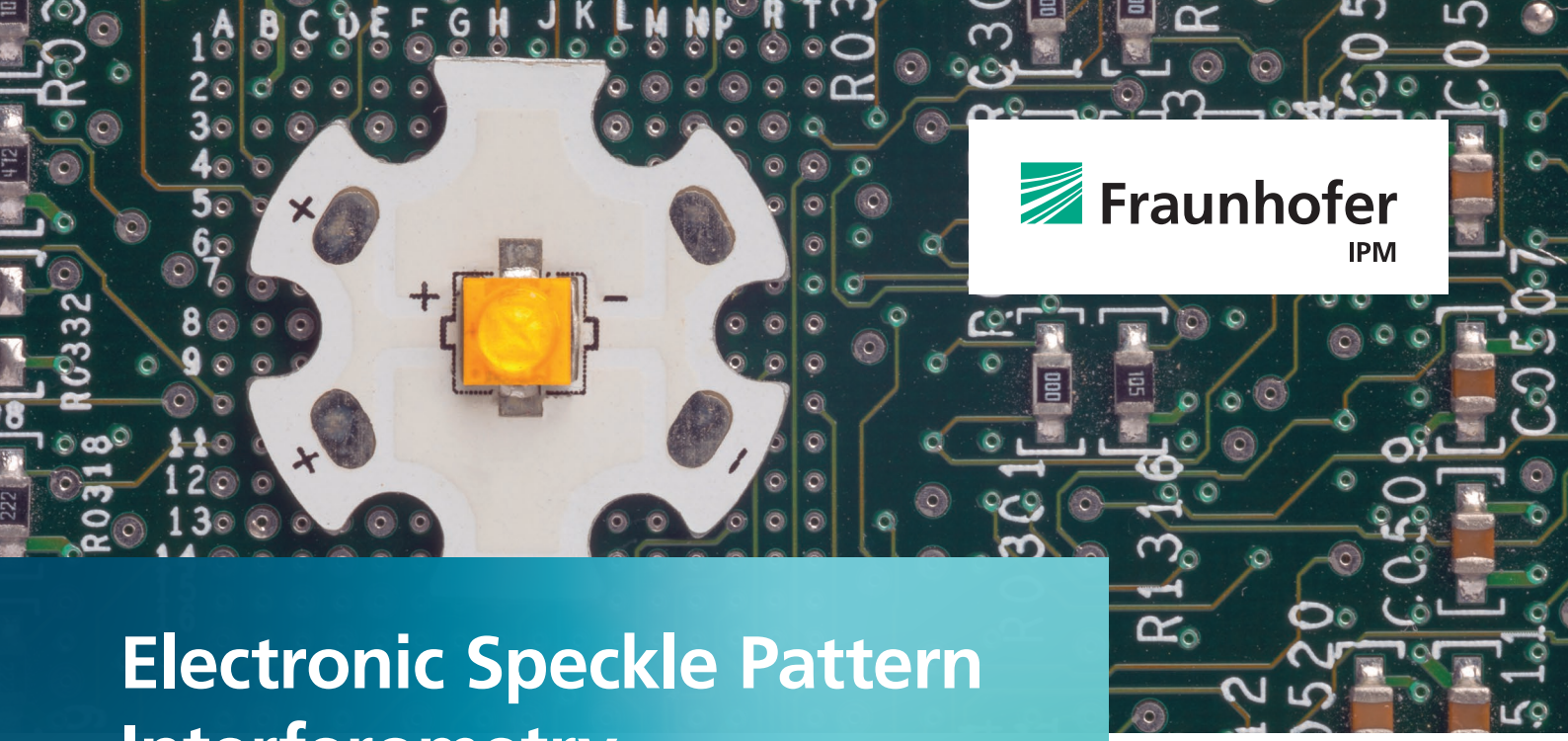


Fraunhofer IPM

Electronic Speckle Pattern Interferometry

Deformation measurement

Fast, imaging and with nanometer accuracy

High-performance electronic components are subject to considerable thermal and mechanical stress. An optical system measures minimal deformations in the production line.

Modern electronic components with high power densities heat up considerably during operation. This leads to mechanical stress and thus deformation of the components. An optical measuring system based on Electronic Speckle Pattern Interferometry (ESPI) can quickly measure minimal changes in component topography providing imaging and an accuracy to the nanometer range directly in the production line.

Spatially resolved, highly accurate surface measurement

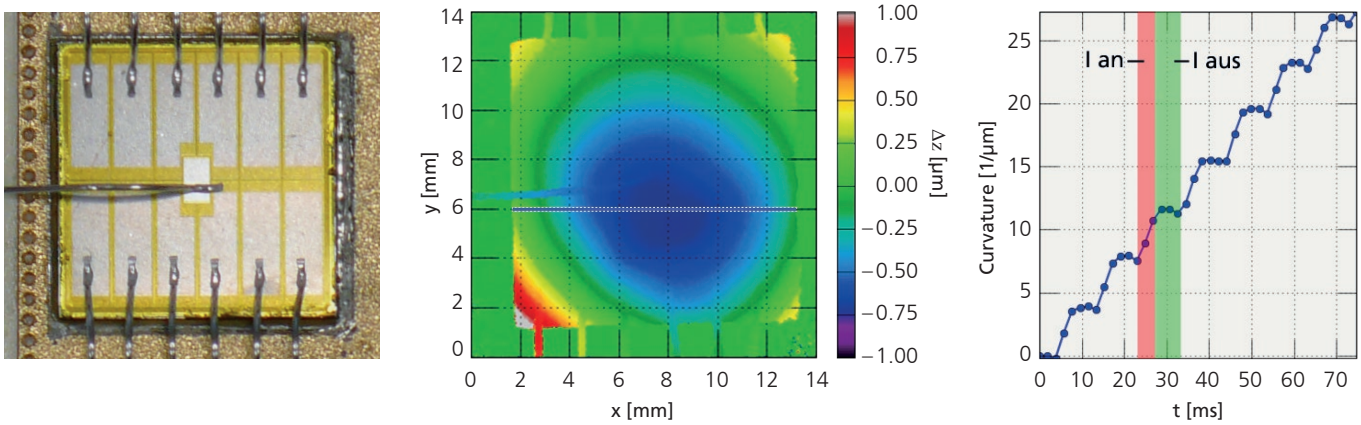
Fast switching and load changes can cause mechanical stress peaks in electronic components that occur locally and within short timeframes, leading to microcracks or broken connections. This is one of the main causes of premature component failure. Conventional failure analysis methods determine the mechanical stress on components indirectly by measuring heat distribution. However, direct measurement of mechanical deformations provides important data for preventing defects and thus premature failures.

The ESPI system developed by Fraunhofer IPM measures microdeformations on component surfaces, e. g. those caused by mechanical or thermal stress, even during rapid operating changes of the electrical component. The method is suitable for monitoring critical production steps and also provides important information for component development, circuit board design, and process development. For example, after the soldering or bonding process, the warping of electrical components under operating conditions can be measured with an accuracy of less than 30 nanometers.

Recognizing and understanding the dynamics of warping in the millisecond range is essential for preventing short-term or local overloading of components during subsequent operation. This is the only way to guarantee consistent product quality and a long service life despite high component stress.

Electronic Speckle Pattern Interferometry ESPI

In the ESPI method, an expanded laser beam is directed onto the surface of the component. This creates a speckle pattern. Due to the component's structure and movement on the scale of a fraction of the wavelength, this pattern changes. Special computer algorithms allow for the surface deformation to be determined very quickly and accurately.



Measurement of a power transistor: Left: Power transistor (11 × 11 mm²). Center: Spatially resolved measurement of the transistor during operation; deformation due to electrical power loss. Right: Time curve of the measured curvature along the profile; dynamic curvature change during pulsed operation (3 A, 50 Hz); the first seven pulses after switch-on are shown.

Precise shape and strain measurement for more accurate simulations

Deformations caused by mechanical stress can lead to irreversible deformations or, if they occur cyclically, to structural failure of the component, resulting in cracks or breaks. The challenge when designing electrical components or printed circuit boards is not only to design the individual component, but to ensure the reliability of the entire electronic system.

Simulation tools can provide support but require precise space and time-resolved input data. In addition to static deformation, dynamic deformation, for example during switching operations, also plays an important role. This requires tools capable of measuring deformation and strain over large areas with sufficient spatial and temporal resolution. By measuring deformations in the nanometer range, mechanical stress can be detected long before failure occurs.

Deformations measurable both horizontal and vertical to surface

Classical ESPI methods use temporal phase shifting. To record the current deformation state, a sequence of camera images is captured, making the method very sensitive to vibrations. The ESPI system from Fraunhofer IPM uses an adapted spatial phase shifting method that obtains all necessary information from a single camera image. This makes it very fast and robust.

The system combines ESPI with high-speed speckle correlation, enabling highly accurate measurements of strain in all spatial directions: 1,000 times per second with a resolution of more than one million pixels. Surface deformations are detected with an accuracy of less than 30 nanometers. This accuracy is sufficient to measure and evaluate deformations such as those that occur in power transistors, integrated circuits, or light-emitting diodes in real time. By reducing the resolution, even higher measurement frequencies can be achieved. This way, even high-frequency components can be examined for mechanical stress in smaller measurement fields.

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