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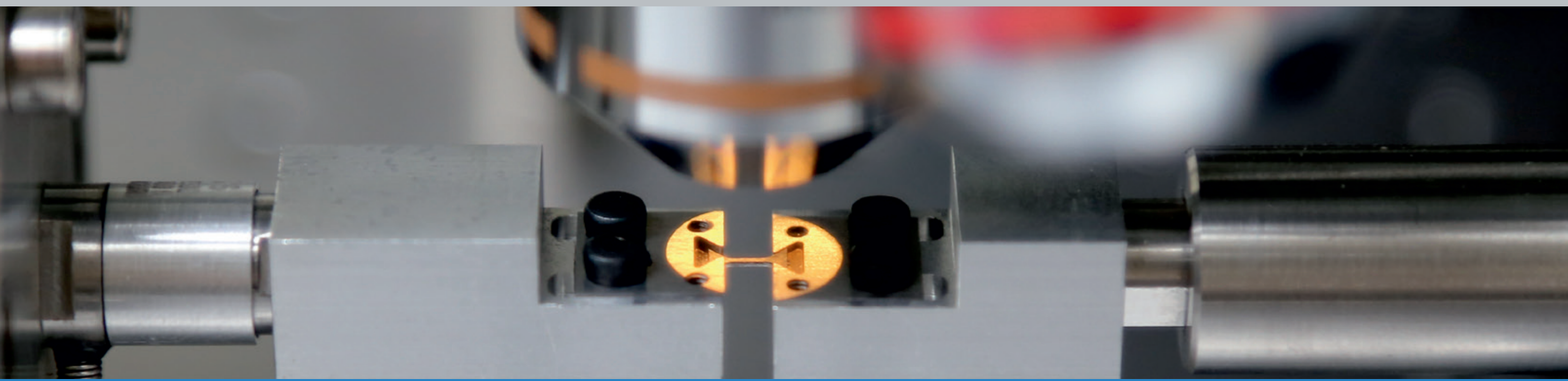
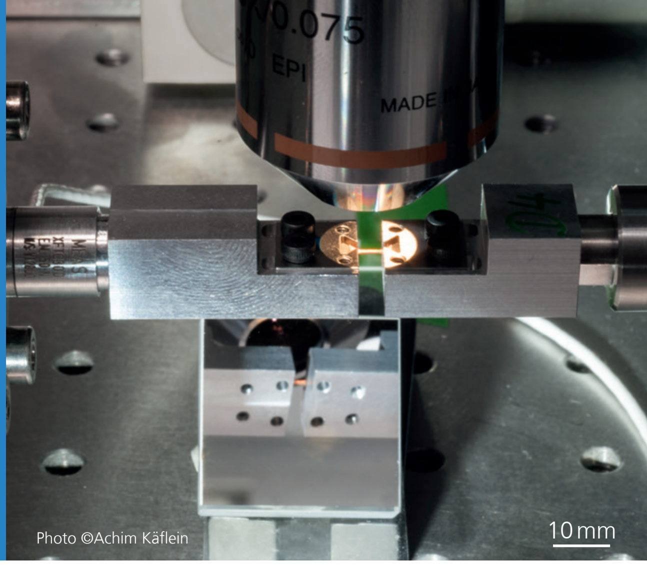


MECHANICAL TESTING OF MESO AND MICRO SAMPLES



Size and scale effects in micro samples

In small parts and components, at least one characteristic dimension is of only a few 100 µm or less.This can lead to local stress states in the microstructure that result in deviation from the expected macroscopic behavior. In addition, the component dimensions are similar to the order of magnitude of the microstructure, which can lead to deformation behavior changes. As a result, material data obtained from macroscopic samples cannot be easily extrapolated to the micro scale, but must instead be determined by means of experiments on the size scale of the aforementioned effects.

Novel setups for micro mechanical testing

Commercially available mechanical testing machines are not usually adequate for the special requirements which are presented by micro sample experimentation, or they function as a hard-to-interpret "black box", which cannot be improved upon because, for example, a separate control of the software is not provided. Therefore, in the meso and micromechanics group of the Fraunhofer IWM, self-developed micro setups are combined with materials science know-how. Against this background, novel micro setups have been developed which, thanks to a linear motor and a piezo actuator, can statically or cyclically apply forces of more than 250 N. The integrated piezo actuator provides high stiffness and a resolution of about 1 nm. This enables stopping experiments as soon as a crack, which would likely lead to failure, becomes critical without completely destroying the sample. The interaction of crack propagation and microstructure can be investigated by a subsequent fracture analysis. Thus, the reliability of micro parts and components can be better assessed, and the data obtained experimentally form the basis for lifetime prediction models on the micro scale.

Static and cyclic tensile tests under specific temperature conditions

Typical sample thickness

- 10 µm … 1 mm

Strain (Digital Image Correlation)

- Strain resolution: ~ 10^{-5}
- Displacement resolution: 10 nm

Load

- Resolution: 1 … 250 mN
- Max. load: +/- 2 … +/- 500 N

Actuation

- Step size: ~1 nm
- Max. velocity: ~ 30 mm/s
- Piezo actuator range: 30 … 180 µm
- Motor range: 0 … 5 cm

Cyclic test characteristic (fatigue)

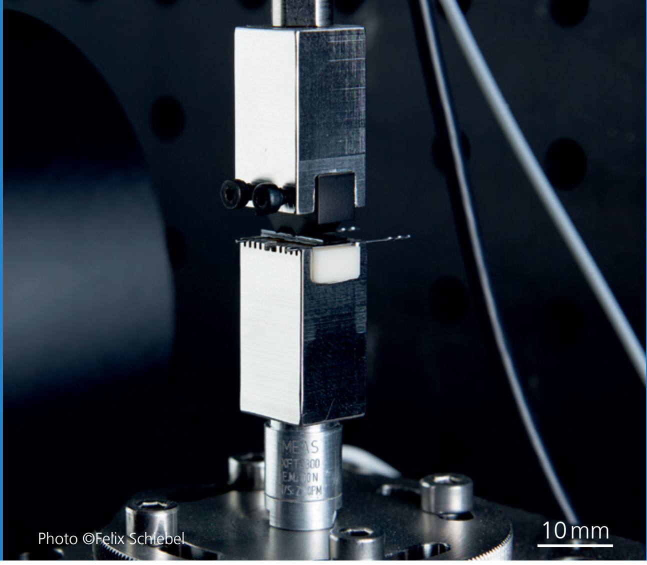
- Load ratio: R > 0
- Frequency: 1 … 100 Hz

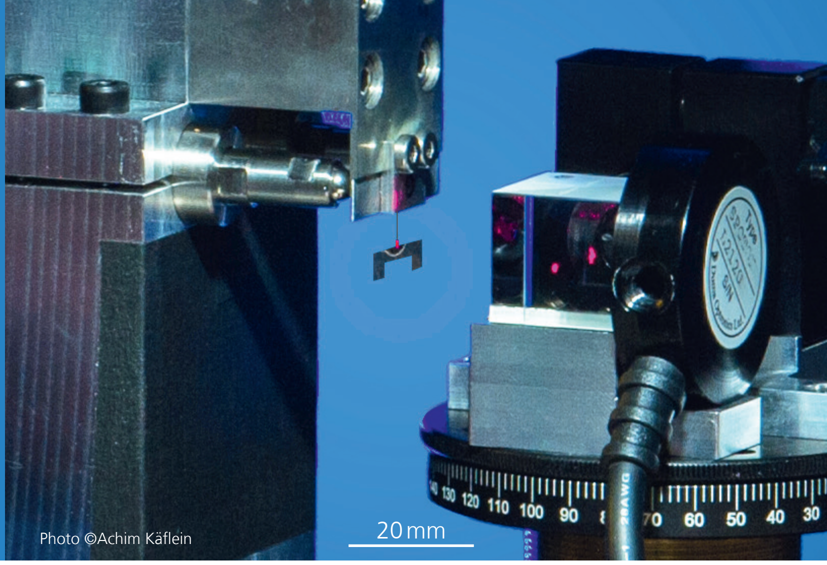
High temperature capabilities

- Resolution: 0.1 °C
- Max. temperature: 1 000 °C

Determination of material parameters

- Young's modulus
- Poisson's ratio
- Yield strength
- Ultimate strength
- Fracture strength
- Endurance limit (fatigue)





Static and cyclic three and four point bending tests

Typical sample thickness

- 50 µm … 1 mm

Strain (Digital Image Correlation)

- Strain resolution: ~ 10^{-5}
- Displacement resolution: 10 nm

Load

- Resolution: 1 … 250 mN
- Max. load: +/- 2 … +/- 500 N

Actuation

- Step size: ~1 nm
- Max. velocity: ~ 30 mm/s
- Piezo actuator range: 30 … 180 µm
- Motor range: 0 … 5 cm

Cyclic test characteristic (fatigue)

- Load ratio: R > 0
- Frequency: 1 … 100 Hz

Determination of material parameters

- Young's modulus
- Yield strength
- Fracture strength (for brittle materials)
- Endurance limit (fatigue)

High and very high cycle fatigue bending resonant tests and damage detection

Typical sample thickness

- 50 µm … 1 mm

Strain (laser measurement)

- Displacement: 1 µm

Cyclic test characteristic (fatigue)

- Load ratio: R = -1
- Frequency: 100 Hz … 2 500 Hz
  (defined by the sample resonant frequency)
- Relative resonant frequency change resolution: 10^{-7}

Determination of material parameters

- Endurance limit up to
  the very high cycle fatigue (VHCF) regime
- Grain orientation of damage initiation sites
- Fracture toughness
- Fatigue crack growth for thin samples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FRAUNHOFER INSTITUTE FOR MECHANICS OF MATERIALS IWM, FREIBURG

Application oriented contract research: mechanics of materials expertise for your competitive advantage

Whether you are in business or a public institution, we address your materials related research and development concerns in application-oriented projects from damage analysis and process development to materials innovations.

We realize solutions for the optimized use of material properties to improve the reliability, life expectancy and safety of components and develop new materials as well as resource-efficient manufacturing processes.

Our research focuses upon material changes in processes and components. For this purpose, we are developing specific material models, characterization and simulation methodologies.

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