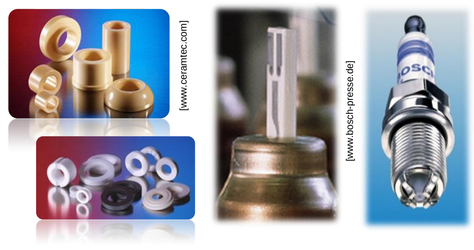
Aalen University

Prediction of Mechanical Properties of Ceramics using Quantitative Microstructure Analysis

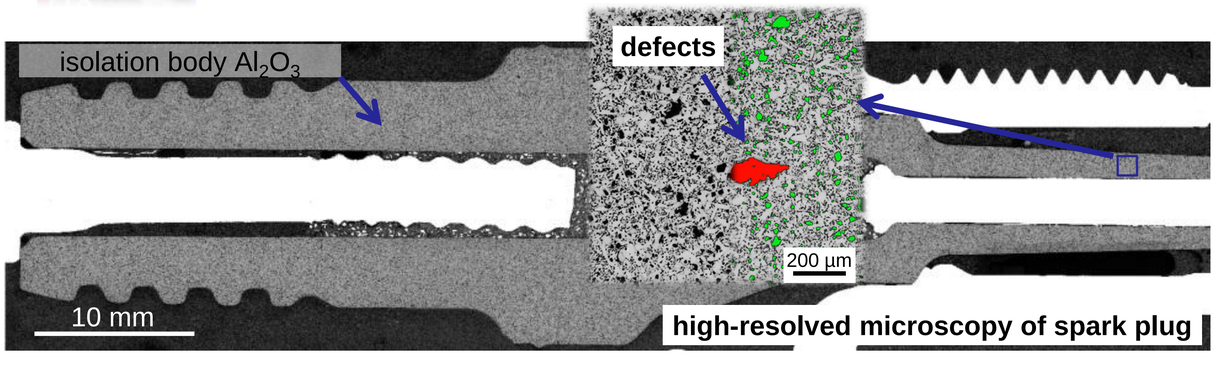
T. Bernthaler, A. Nagel, G. Schneider, V. Knoblauch, M. Hoffman

Motivation and advantage

Determination of material properties (e.g. reliability, strength) of high-performance ceramic components

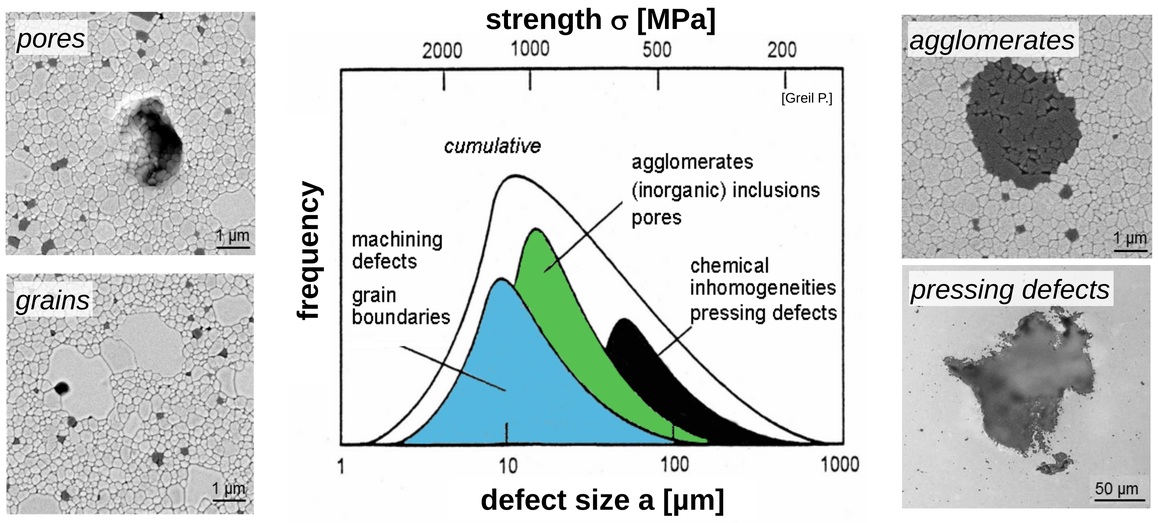


- **localised analysis** on real components
- **consideration** and **visualisation** of **inhomogeneities** and **processing** influences
- development of processing on **real components** and **not on model samples**

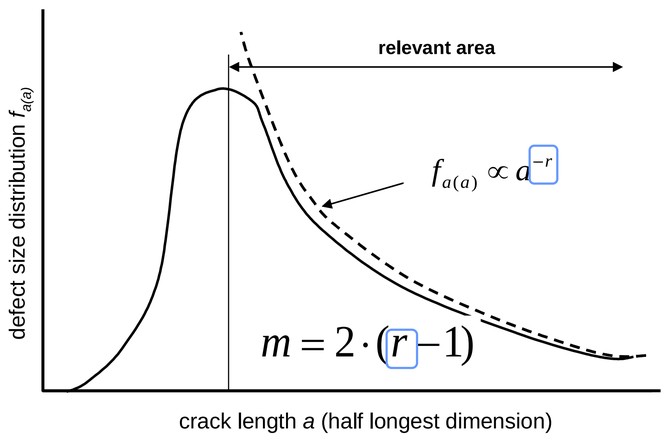


Problems of ceramics and theoretical background

1. **brittleness** → significant **lower toughness** (K_{Ic}) compared to metals/polymers
2. **reliability** → **strong scattering** of strength (**Weibull modulus m**) due to various defect characteristics and defect sizes



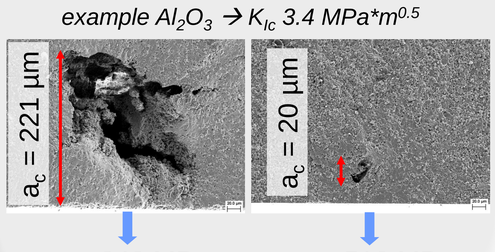
Weibull modulus *m* – defect size distribution



strength σ – defect size *a*

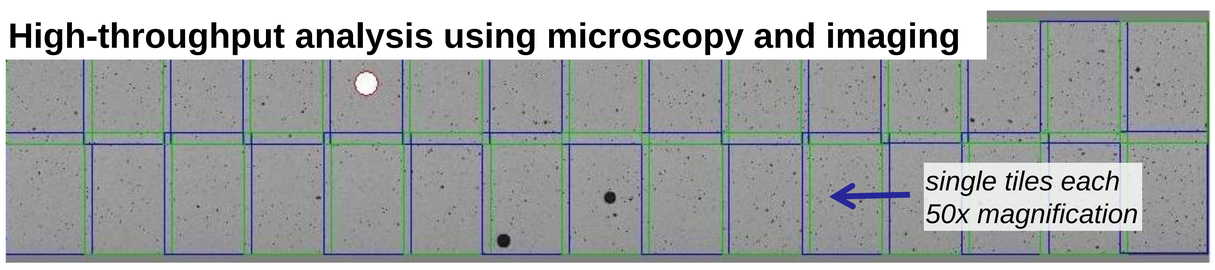
$$\sigma_c = \frac{K_{Ic}}{Y\sqrt{a_c}}$$

*example Al_2O_3 → K_{Ic} 3.4 MPa*m$^{0.5}$*

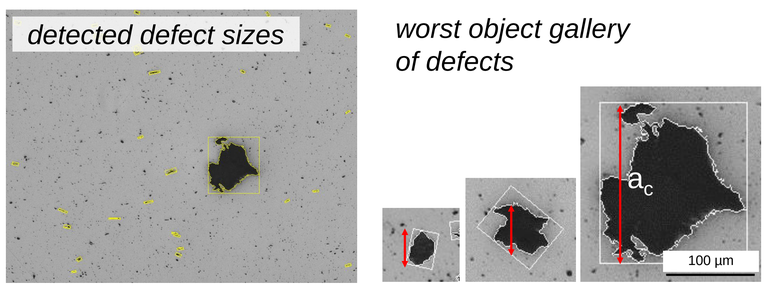


Approach

High-throughput analysis using microscopy and imaging

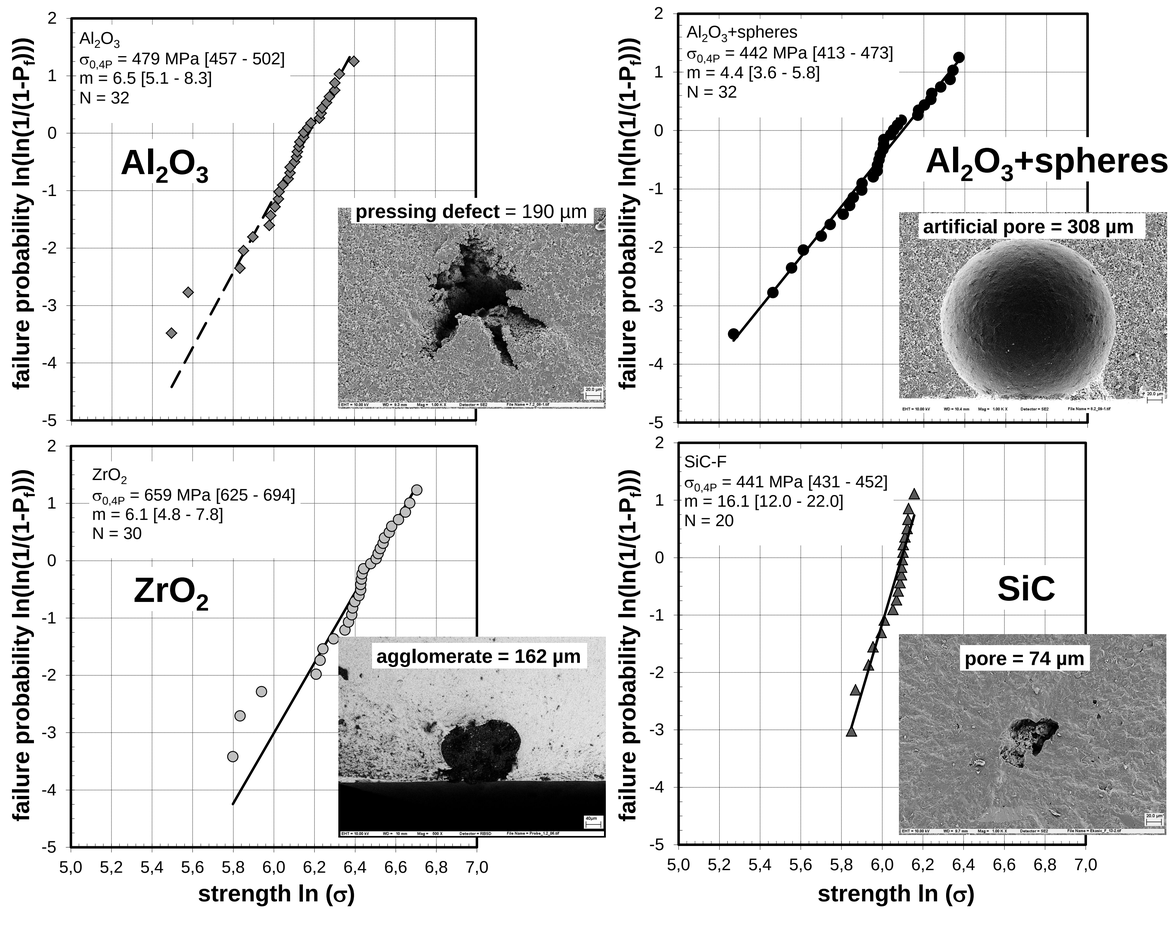


ceramographic preparation
↓
automated microscopy
image analysis defect distribution
↓
prediction Weibull modulus / strength
based on defect size distribution

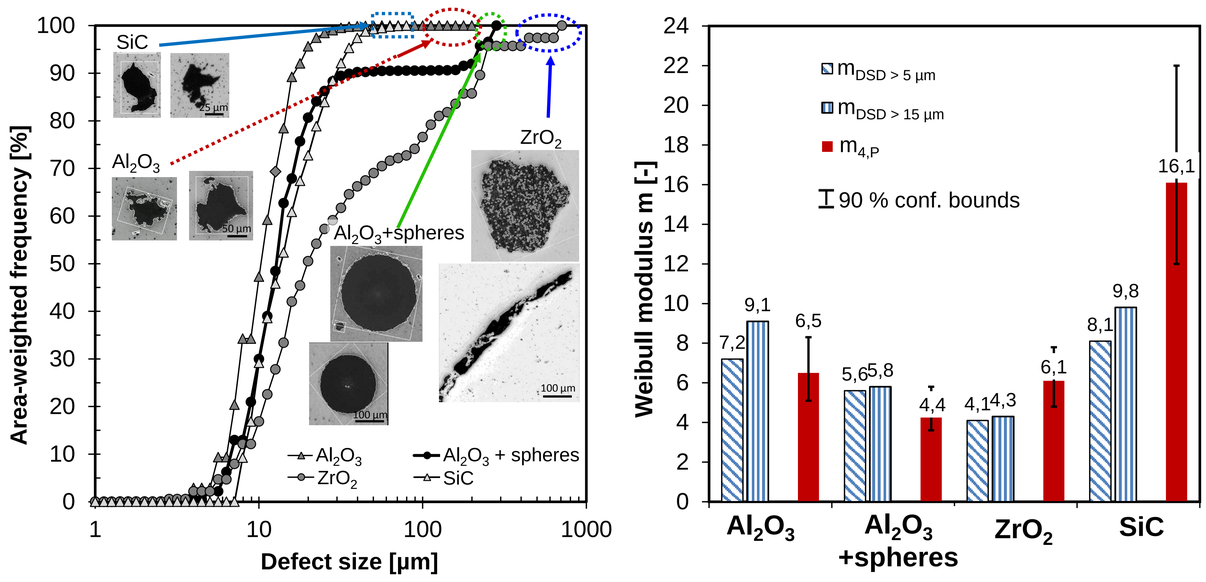


Results

Four-point bending strength distributions of investigated ceramics

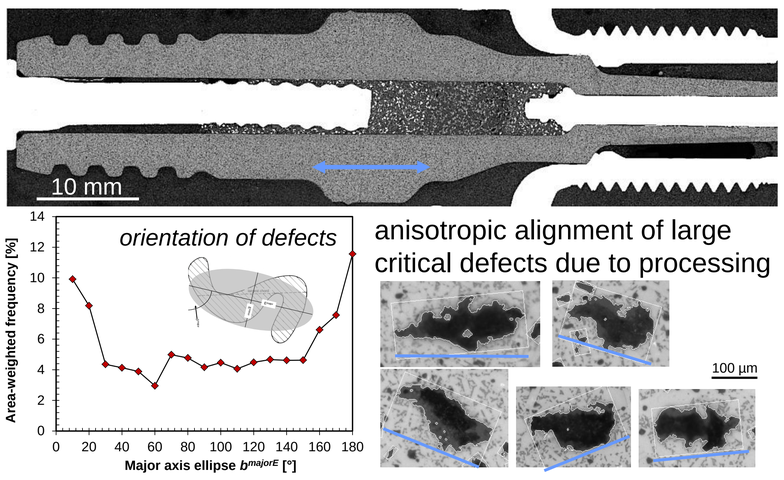


Defect size distributions and predicted Weibull modulus



Outlook and potential of technique

Microstructural analysis of Al_2O_3-isolation body spark plug



Issues

- processing influence
  → powder preparation
  → cold isostatic pressing
- anisotropic behaviour of defects due to processing
- reliability
  - electrical break down
  - strength
- general increased quality

Conclusions

- **ceramography** delivers almost **identical defect characteristics** compared to **mechanical testing & fractography**
- **prediction** of **Weibull modulus** shows close **accordance**
  proposed method allows to determine the scattering of strength data
- **Processing**, which often determines the defect characteristics and thus is responsible for the scattering can be **optimized applying this advantageous method**
- **promising technique** to characterize and **improve high-performance ceramic components**, e.g. spark plugs, sensors

PhD-thesis Timo Bernthaler in cooperation with University of New South Wales, Sydney, Australia

contact: timo.bernthaler@htw-aalen.de