



Integrated topographic SEM imaging for software assisted fractography

make · explore · discover



Outline

- // Fractography
- // Machine Learning
- // SEM Topography
- // iFracto project
- // Results
- // Outlook



Interpretation of fracture surfaces
with Machine Learning based on SEM
images and topography data



BAM – Federal Institute for Materials Research
and Testing

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GFAI – Institute for Applied Informatics

Ulrich Sonntag, Benny Botsch

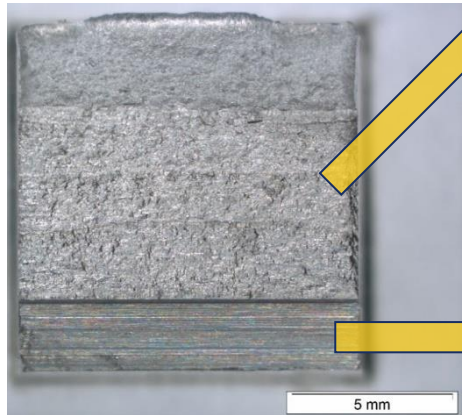


point electronic GmbH

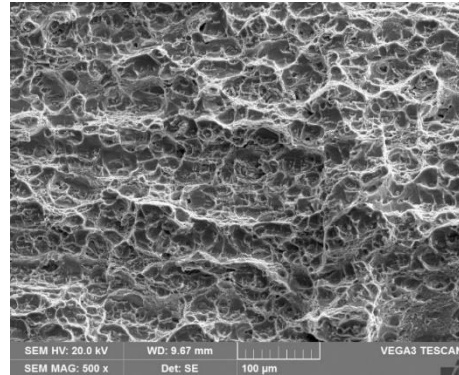
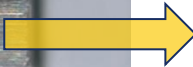
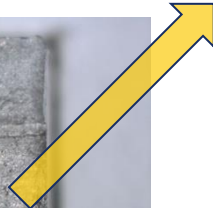
Fractography - Principles



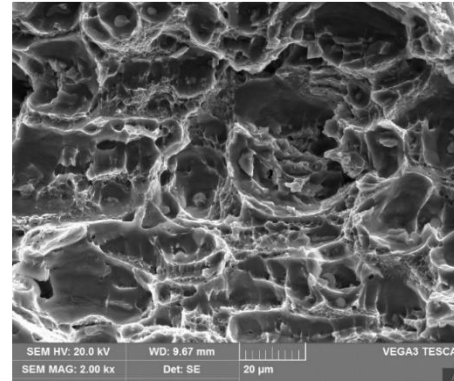
ISO compatible fracture test



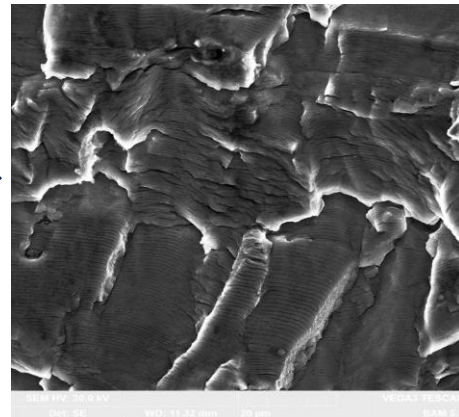
Sample (ISO): AlZn4,5Mg1



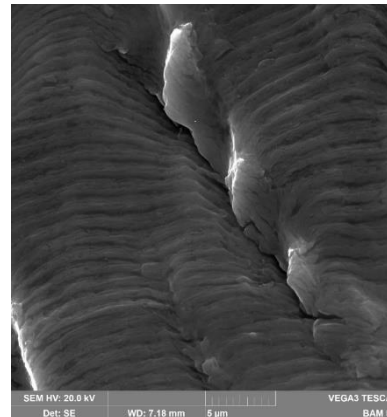
Forced fracture



Dimpled surface (honeycombs)



Fatigue fracture

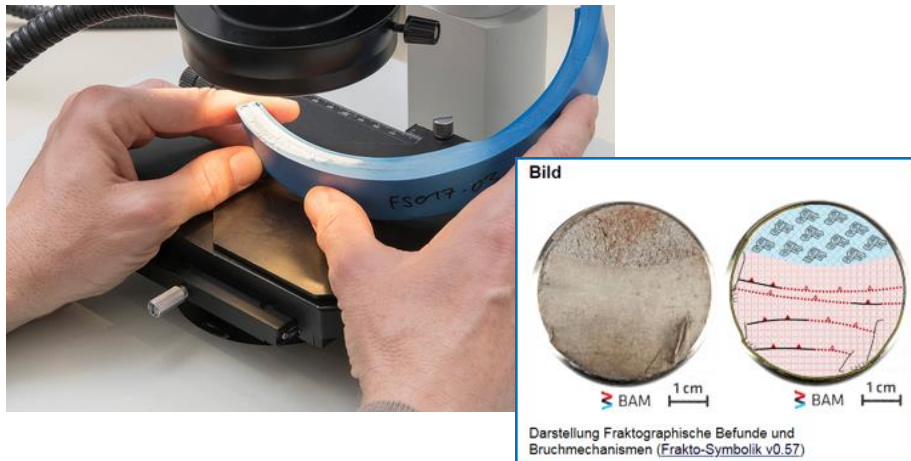


Oriented facets

- // Evaluation and description of fracture surface characteristics
- // Determination of the fracture mechanism
- // Identify the cause of the failure
- // Different crack types produce characteristic surface features

Fractography – Typical applications

- // Failure analysis
- // Forensic investigations
- // Material science, testing, research



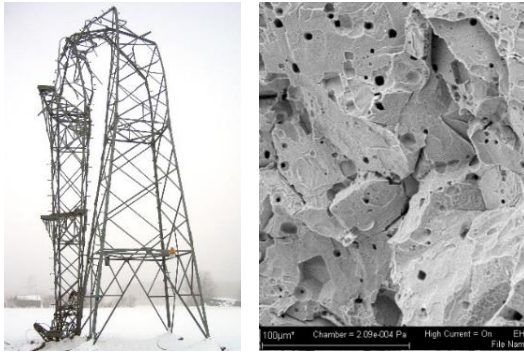
Wheel rim
(ICE accident Eschede 1998)



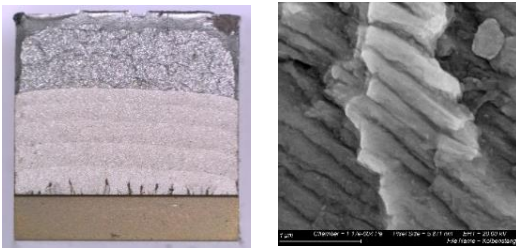
Power pole
(Snow storm, Northern Germany 2005)

Fractography - Practices

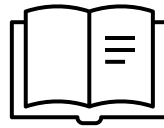
Damage case: Samples



Lab experiments



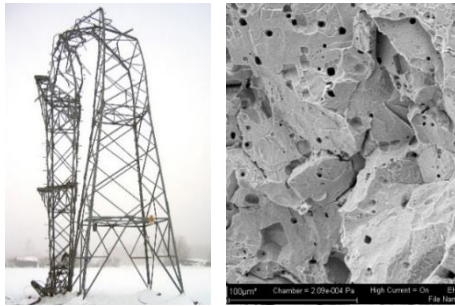
Archived knowledge



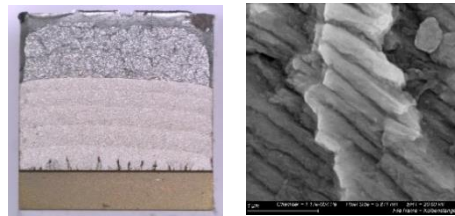
- // LM images for overview on macroscopic level
- // SEM images for microscopic details
- // Comparative mechanical testing and literature as evaluation base
- // Very complex analysis requires considerable experience
- // Time consuming work, heterogeneous skills required

Computer assisted fractography

Damage case: Samples



Lab experiments



Fracto
DataBase

Verification

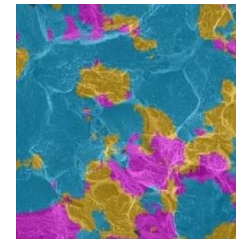


// Artificial Intelligence:
Machine Learning and
dedicated Knowledge Base

// Automated imaging (stage,
different magnifications)

// Additional information:
Multi-channel signals (SE,
4Q-BSE), Topography,
Metadata

Proposed results



// Intuitive user interface
(pre-analysis, report
generation, database
connection)

Machine Learning
Tool

Project iFracto



- // SEM Operator
- // Expert Knowledge
- // Fractographic Database

iFracto



- // End-User Application
- // Machine Learning Engine

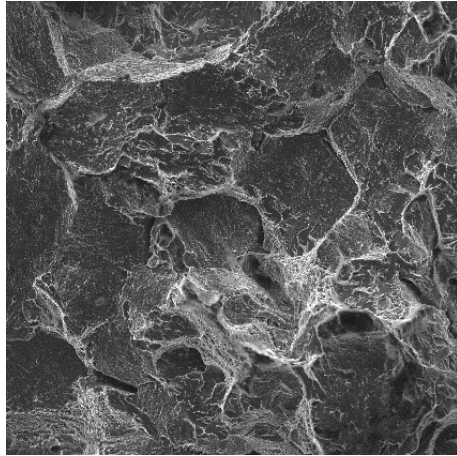


- // SEM Data Workflow
- // Topography Acquisition

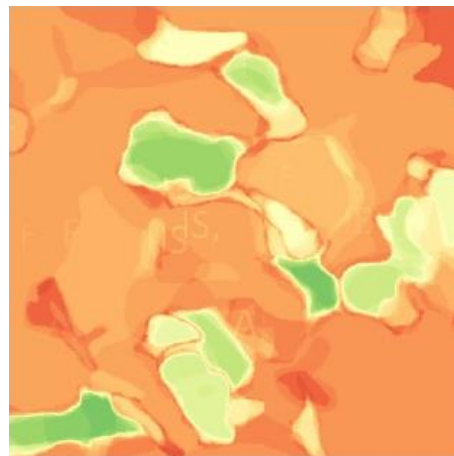
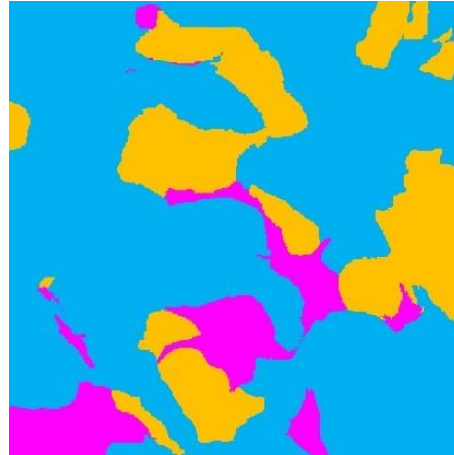
- // Software development: quantitative determination of fracture characteristics and fracture mechanisms
- // Applies machine learning algorithms and image segmentation
- // Provide classifier from training network based on expert knowledge
- // Workflow for multichannel data acquisition and processing
- // Including automated acquisition of surface topography

Machine Learning

Knowledge base / Round robin tests



Sample #16 34CrNiMo6



Kürzel	Vorgegebene Merkmalsbezeichnungen:	Übersetzung g von	z u	Farbcode neu	Bemerkung
A	A: Waben	255 0 255			
B	B: Scherwaben	204 153 255			
C	C: Mikrowaben	255 204 255	A	255 0 255	
D	D: Schwingstreifen	0 255 0			Inkl. V, OS, ZI
E	E: Spaltflächen	255 192 0			Inkl. Q, Q1-Q4, TS
F	F: Offen liegende Korngrenzen	0 176 240			Inkl. IS, IB, IF
G	G: Kristallographisch orientierter Bruch	0 112 255			
H	H: Lamellenartiges Gefüge, z.B. Perlit	64 192 0			

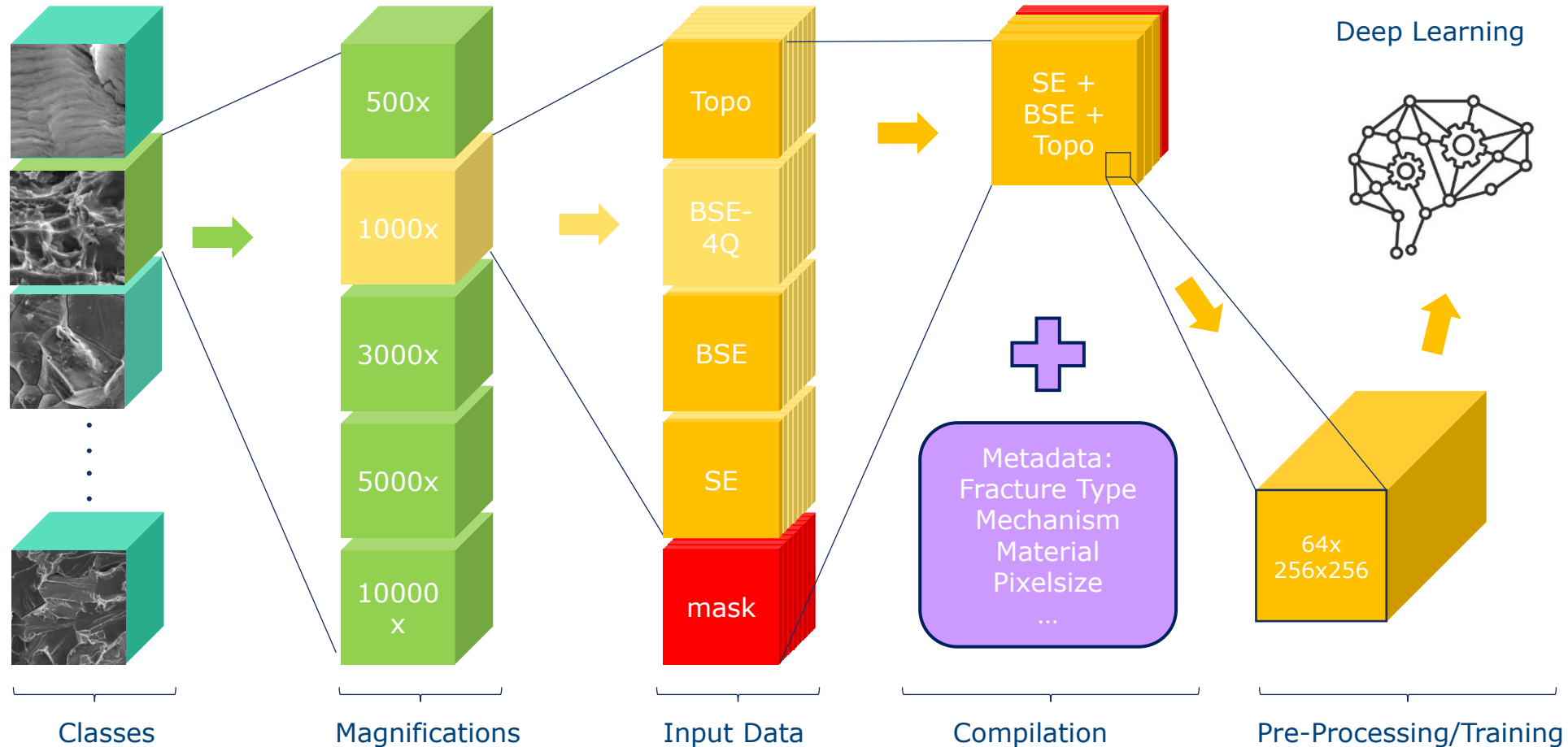
// 26 participants in industry and research institutes

// 46 images from lab generated fracture surfaces

// Results: Highlighted image areas for fracture mechanisms and surface characteristics

Machine Learning

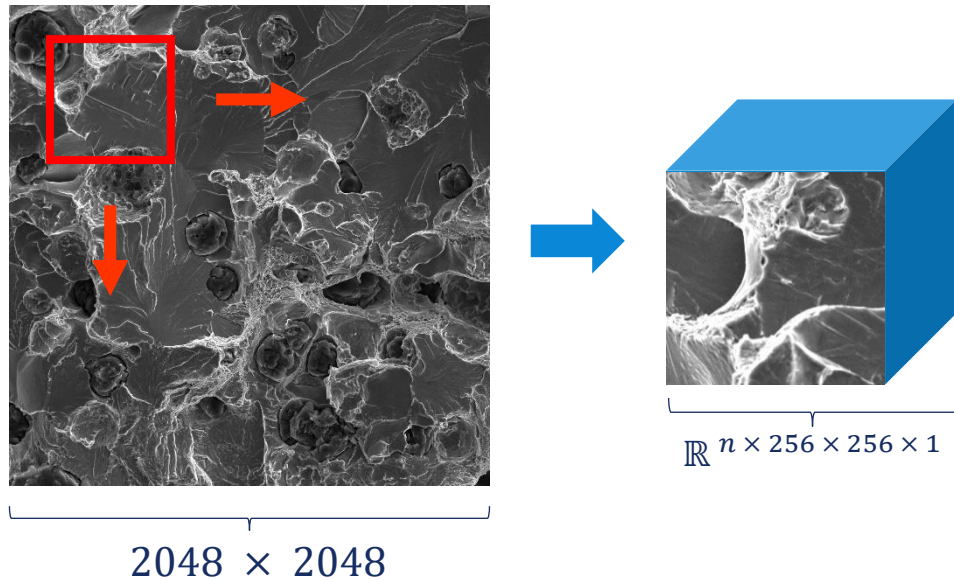
Training data management



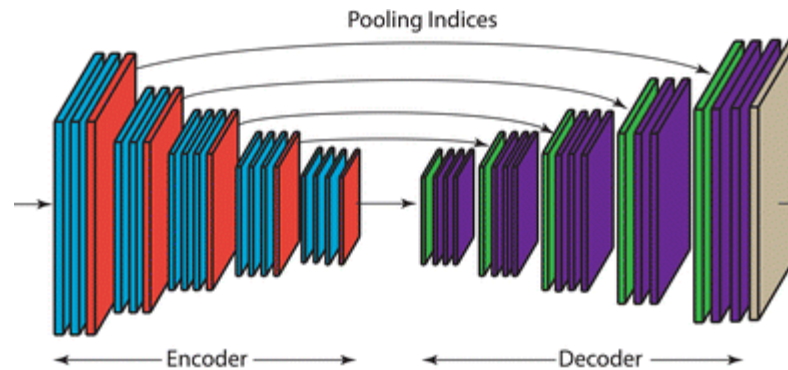
Machine Learning

Training network / Classifier (SE images)

Training Data

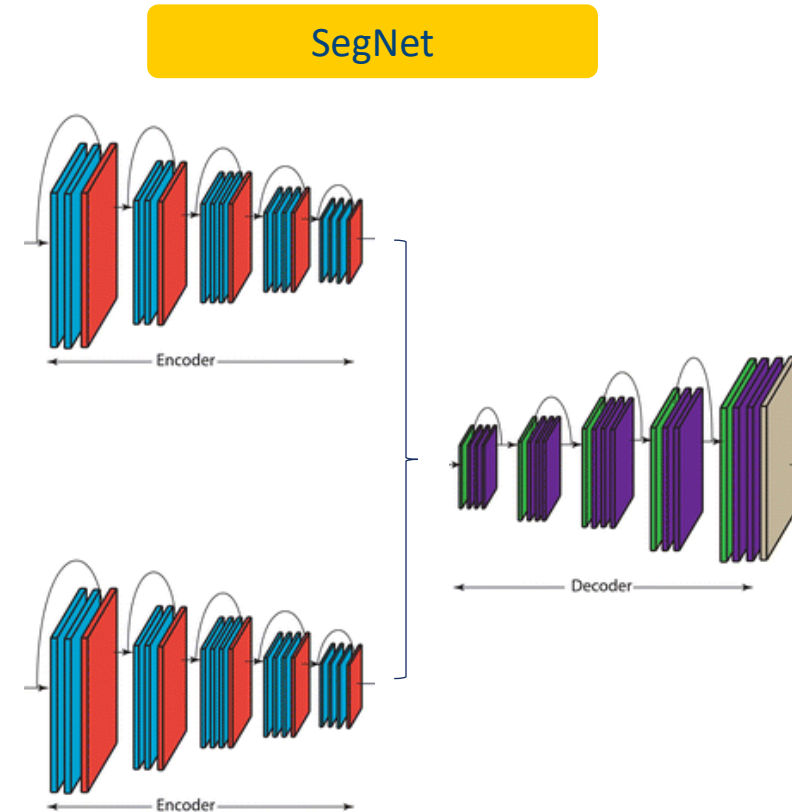
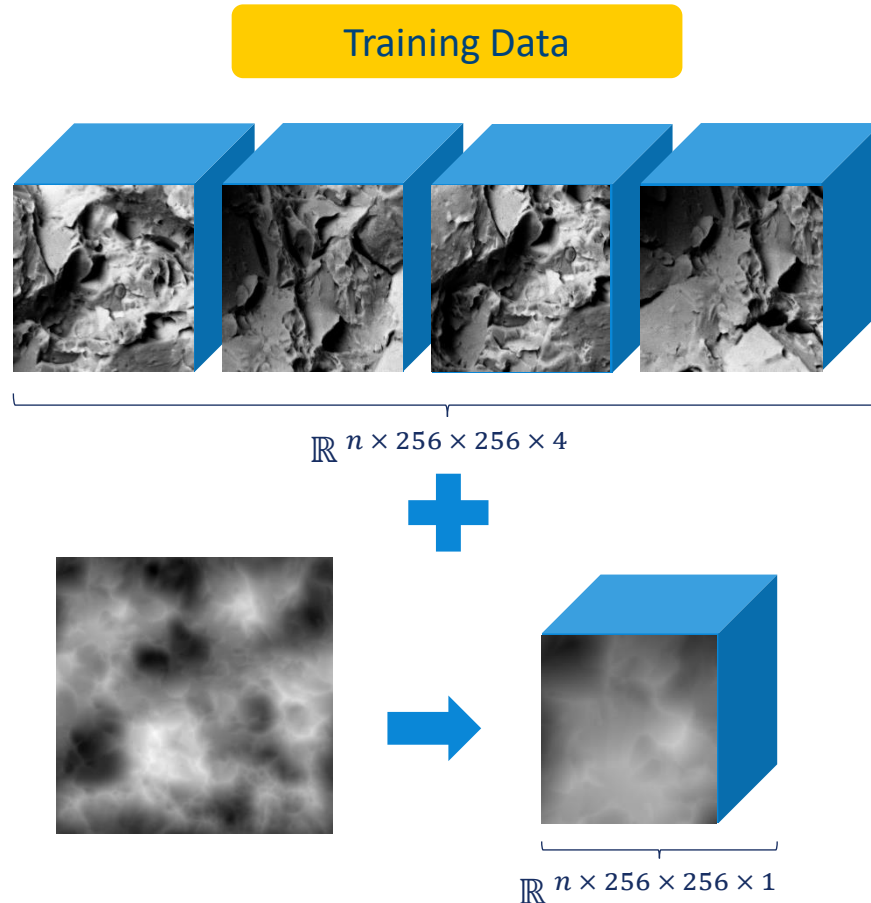


SegNet

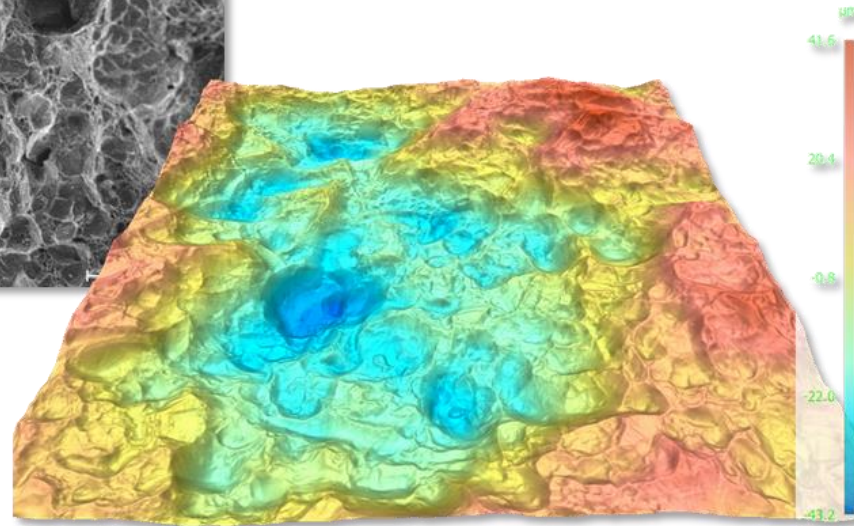
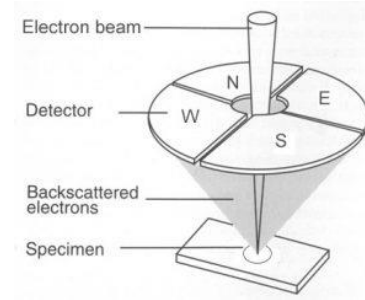
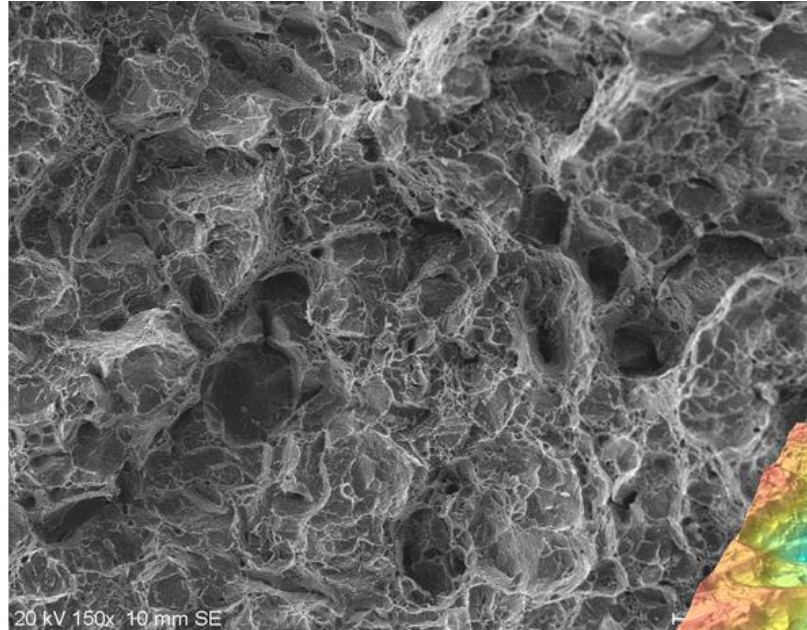


Machine Learning

Training network / Classifier with additional height maps

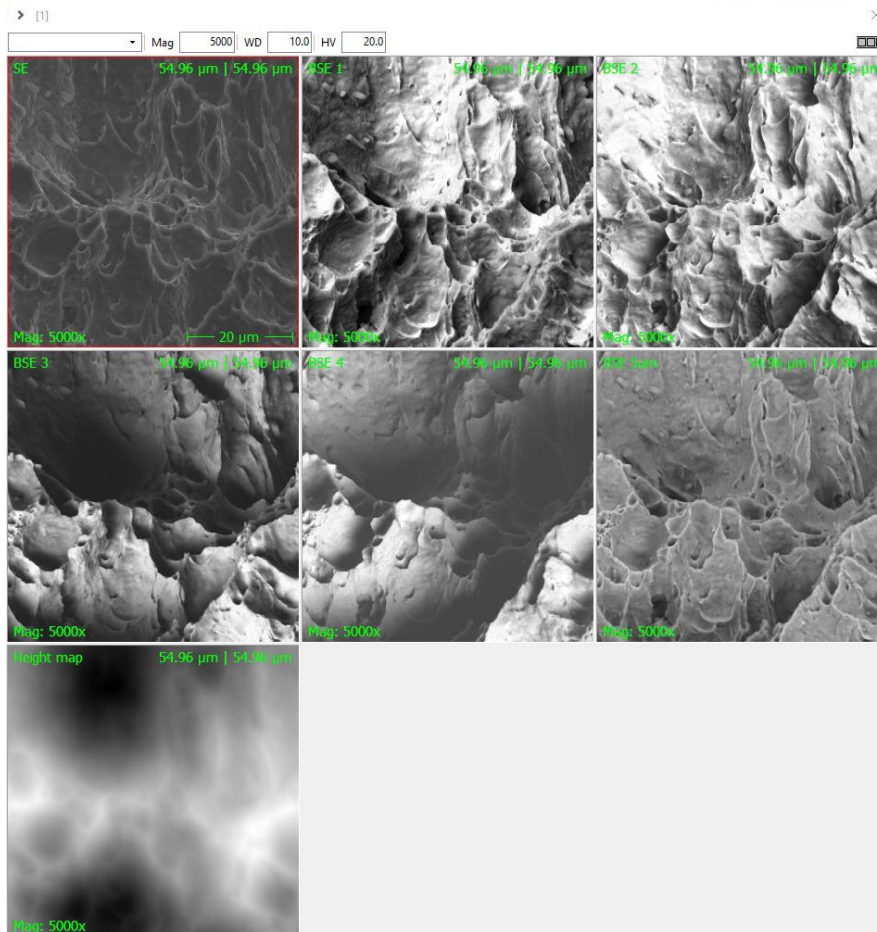


SEM Topography



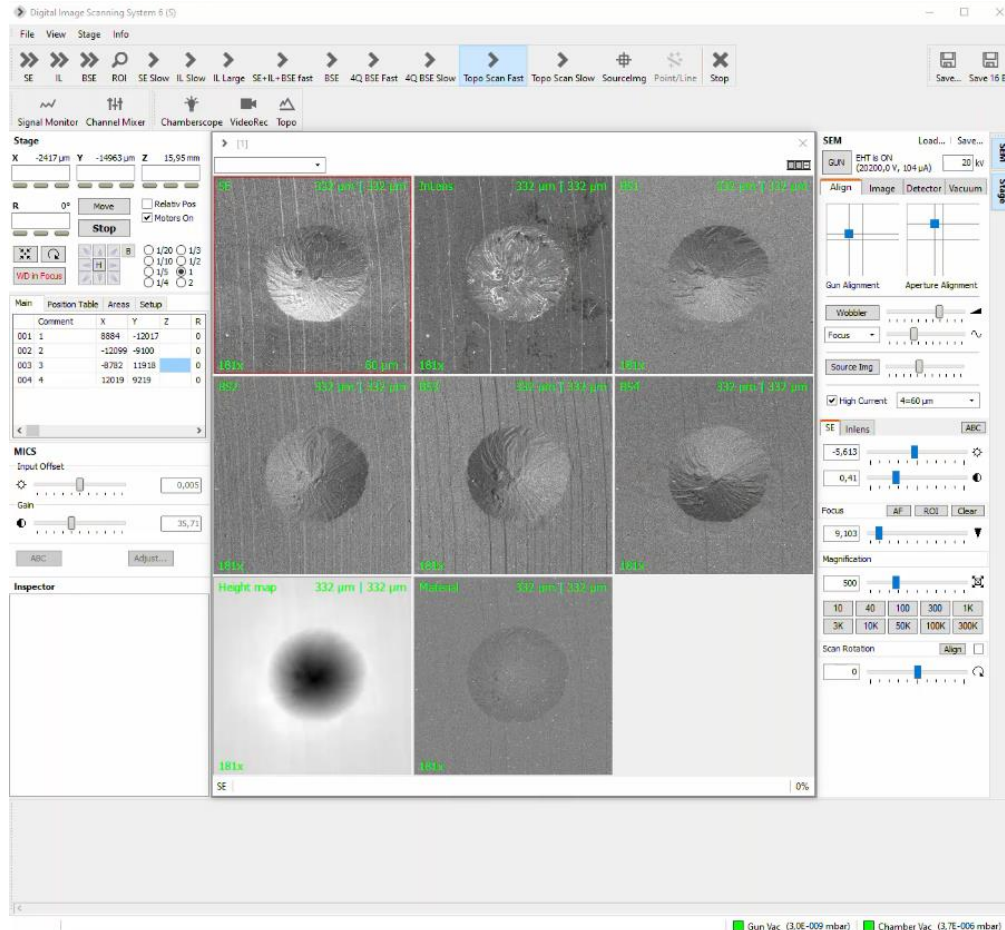
- // BSE detector with 4 symmetric segments and calibrated signal acquisition
- // Surface reconstruction with Shape-from-Shading, no sample tilting
- // Integrated 3D calibration for quantitative height maps

Automated multichannel data acquisition



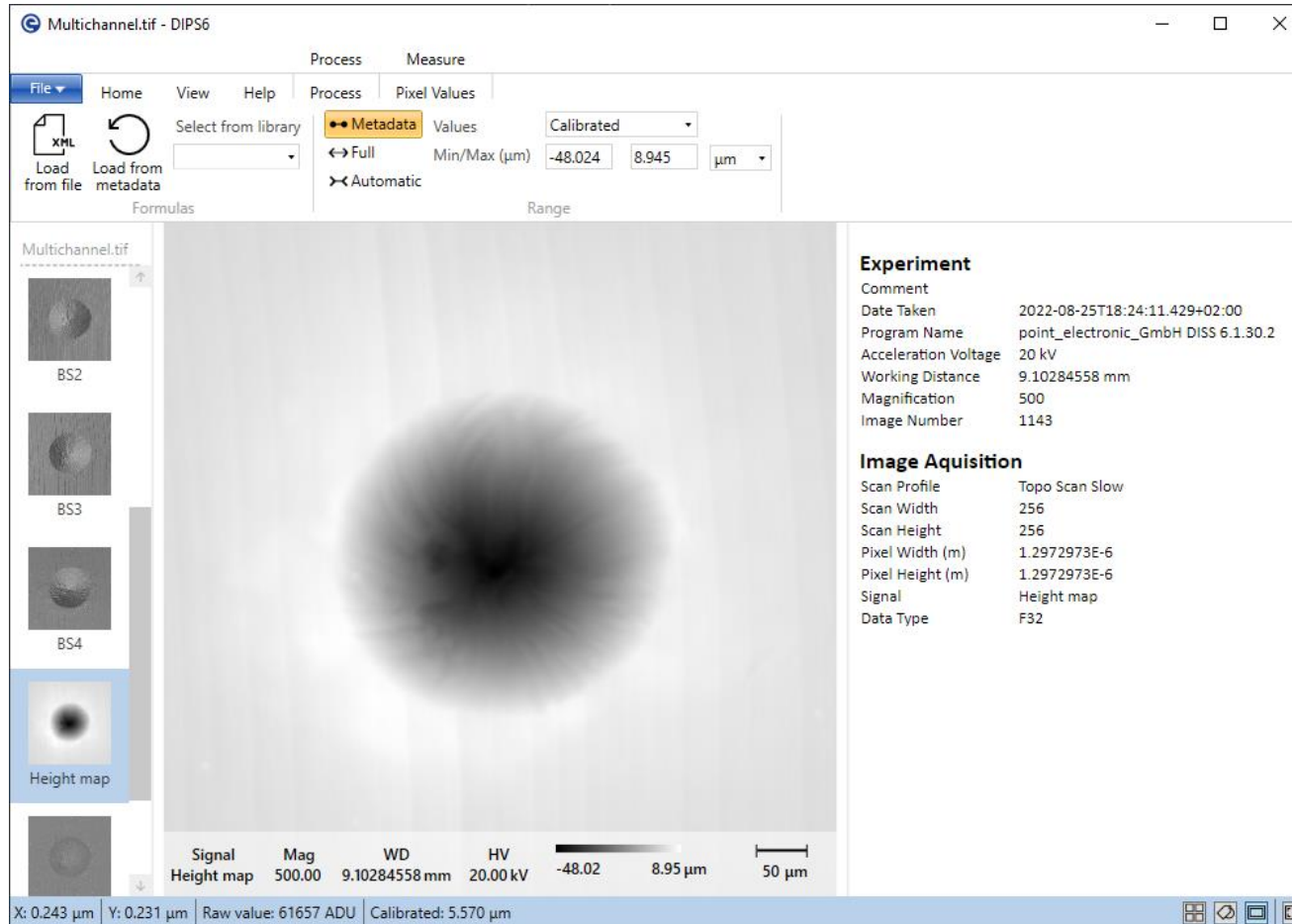
- // Scan control and multichannel signal acquisition
- // Additional channels for height map and BSE compositions (material and topographic contrast) at the same time
- // Remote control for image and height acquisition including data storage
- // Apply your scripts for automated workflows with integrated JSON interface

Automated multichannel data acquisition



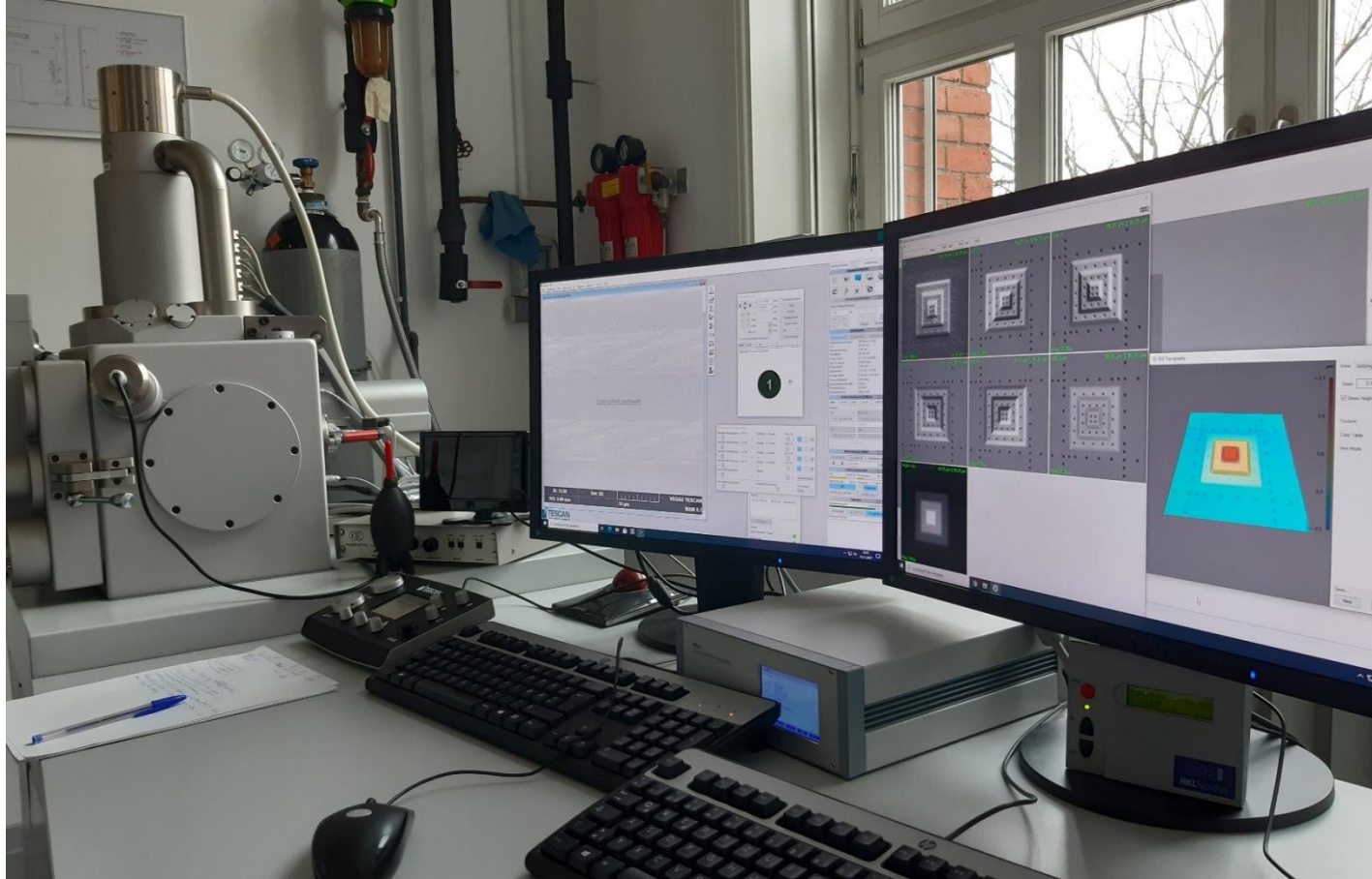
- // Scan control and multichannel signal acquisition
- // Additional channels for height map and BSE compositions (material and topographic contrast) at the same time
- // Remote control for image and height acquisition including data storage
- // Apply your scripts for automated workflows with integrated JSON interface

Multichannel data exchange



- // Standard data formats: Multipage-TIFF including all metadata
- // 8 or 16 bit data with calibration information
- // Additional formulas for quantitative calculations
- // Open access to metadata (XMP)
- // DIPS6 viewer (point electronic)

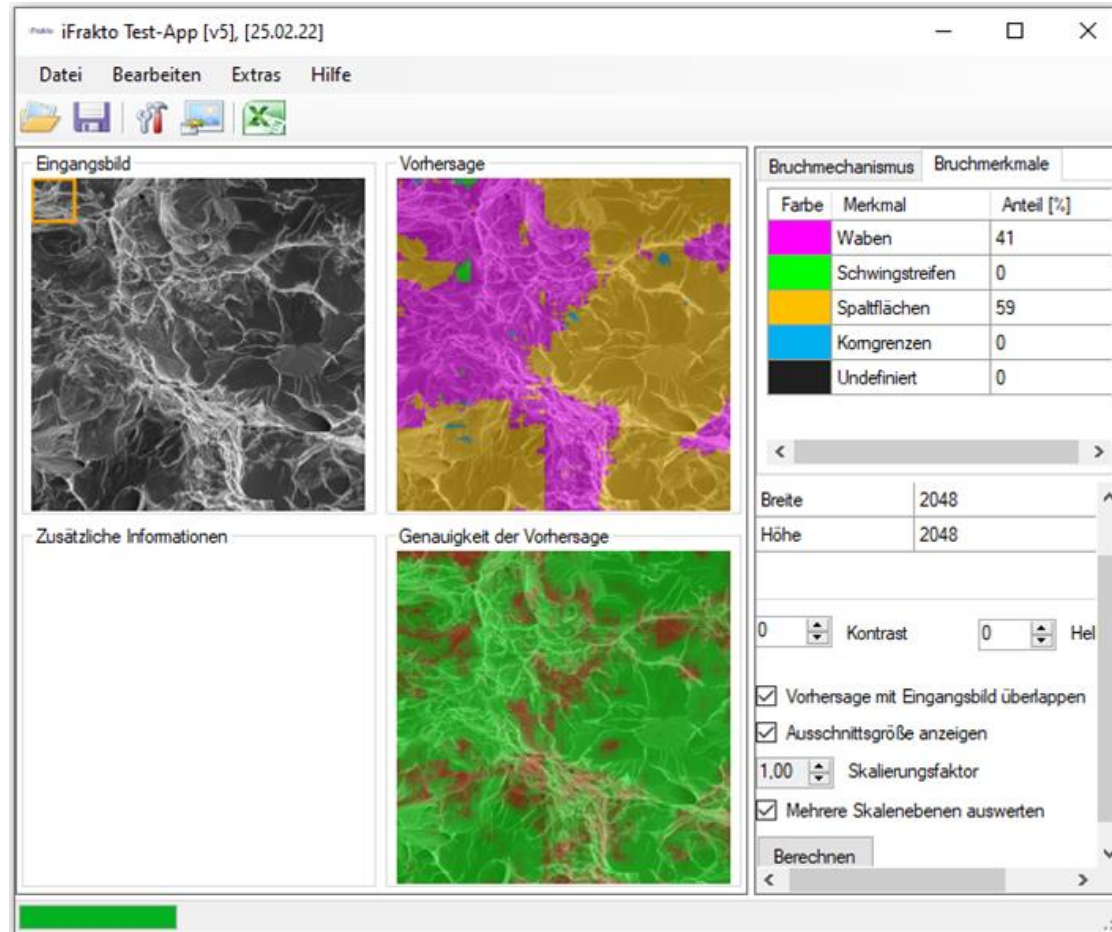
Applied system for iFracto project



- // Tescan Vega3 at Federal Institute for Materials Research and Testing (BAM, Berlin)
- // 4Q-BSE Detector with DISS6-Topography (point electronic)
- // Calibration with 3D reference sample (MMC-80-4BSD)
- // Fracture samples
- // Image data, height data

Results

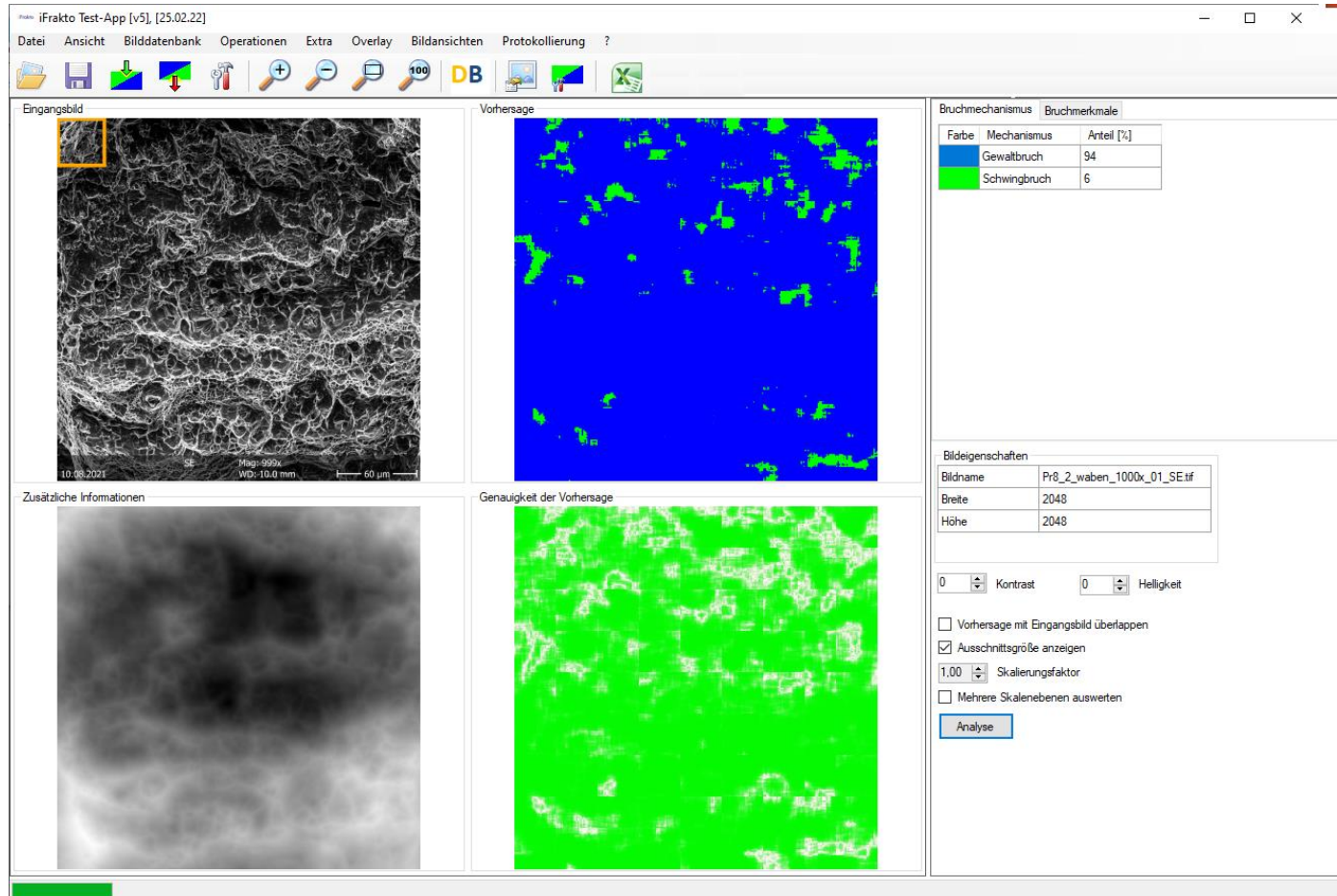
Software prototype



- // Predicted fracture surface characteristics
- // Predicted fracture mechanism
- // Accuracy of the prediction
- // Color editor and data overlay
- // Data report (Excel)

Results

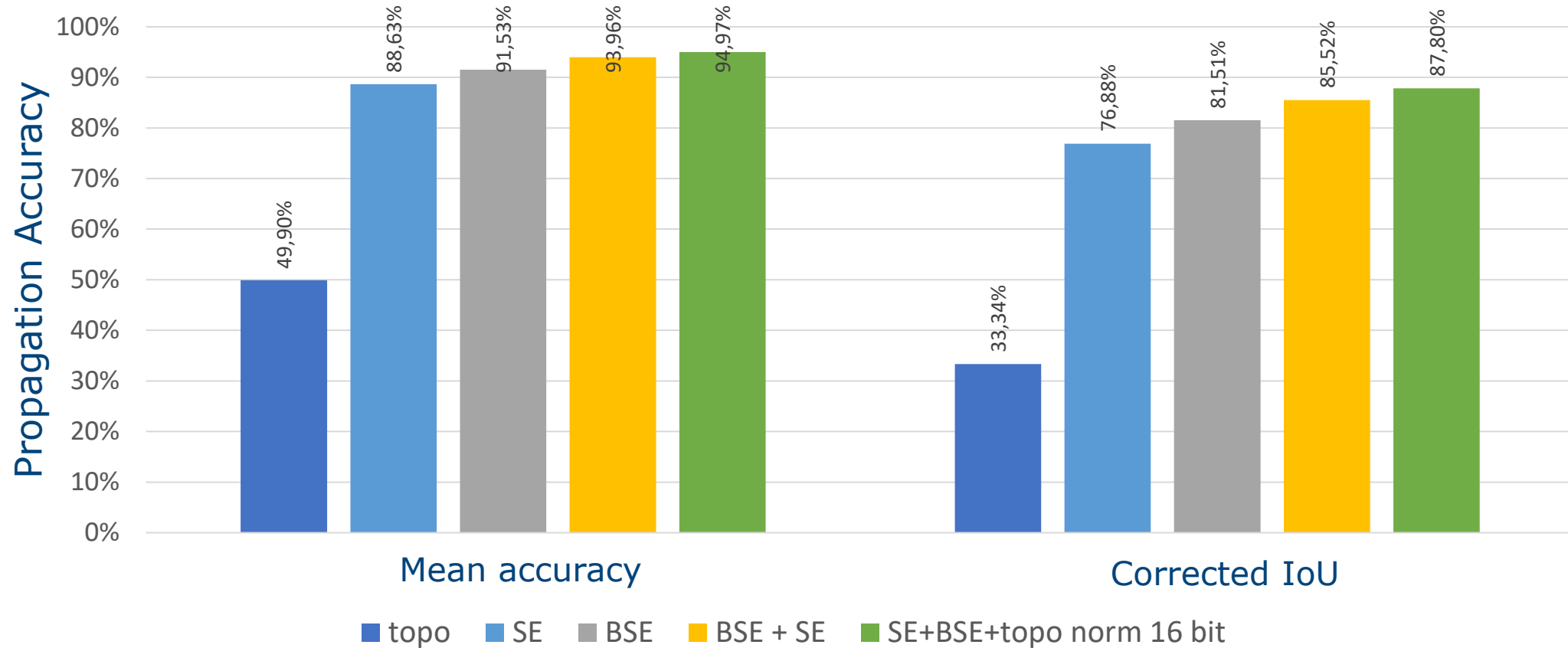
Software prototype



// Topography data (height map) as additional input

Results

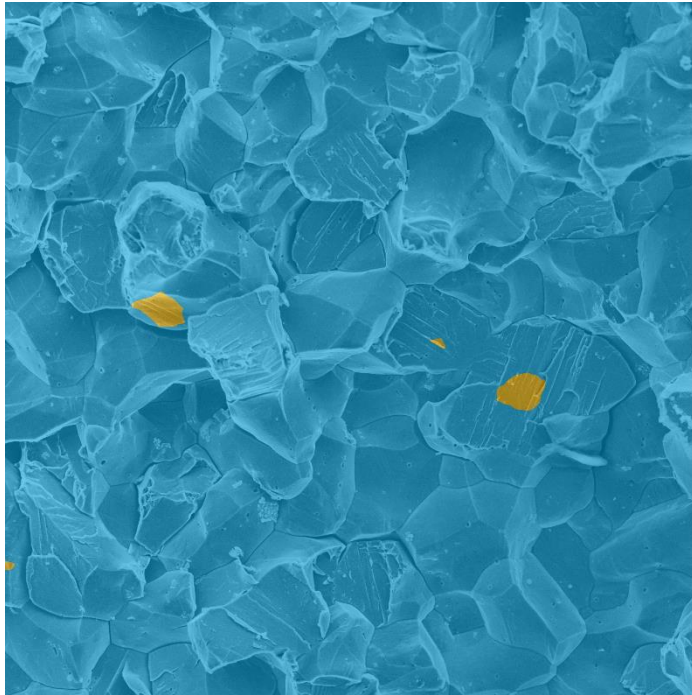
Improved results with topographic data



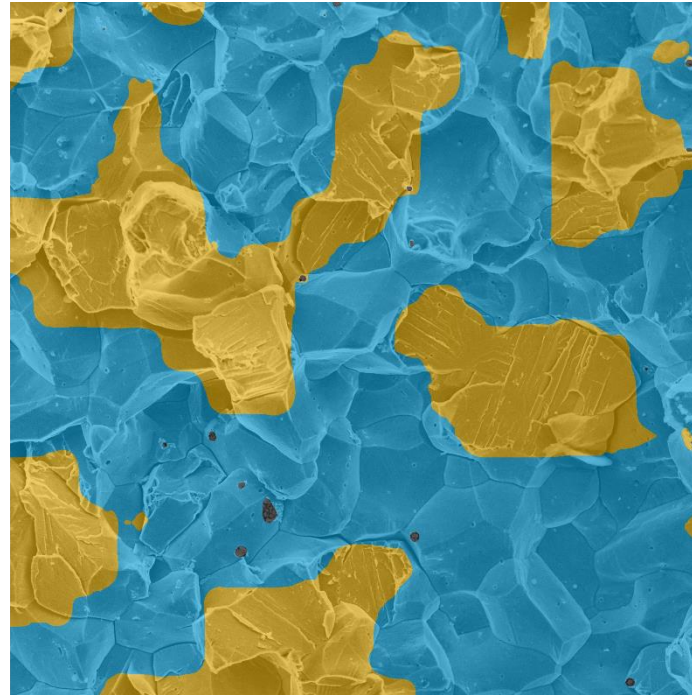
Comparison of fracture surface characteristics (IoU = Intersection over Union)

Results

Improved results with topographic data



Predicted surface characteristics with SE images

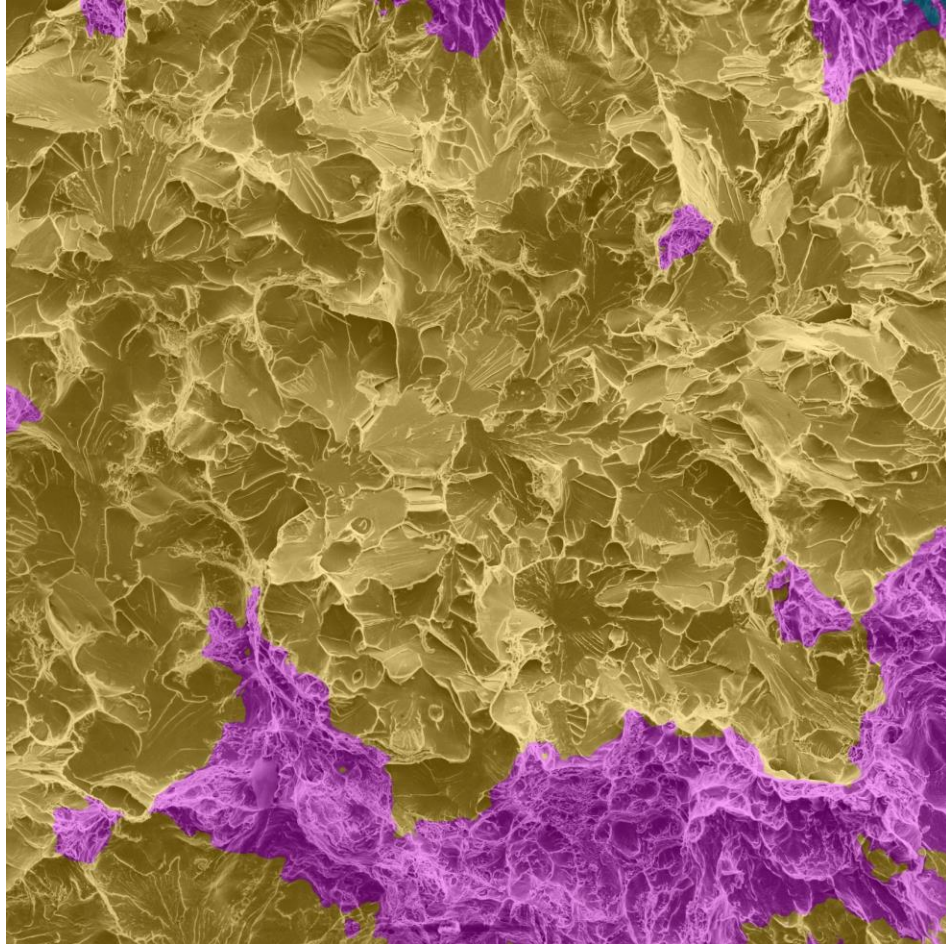


Improved results with additional topographic data

	Dimple surface (honeycombs)
	Cleavage areas
	Grain boundaries
	Facets
	Not allocated

Results

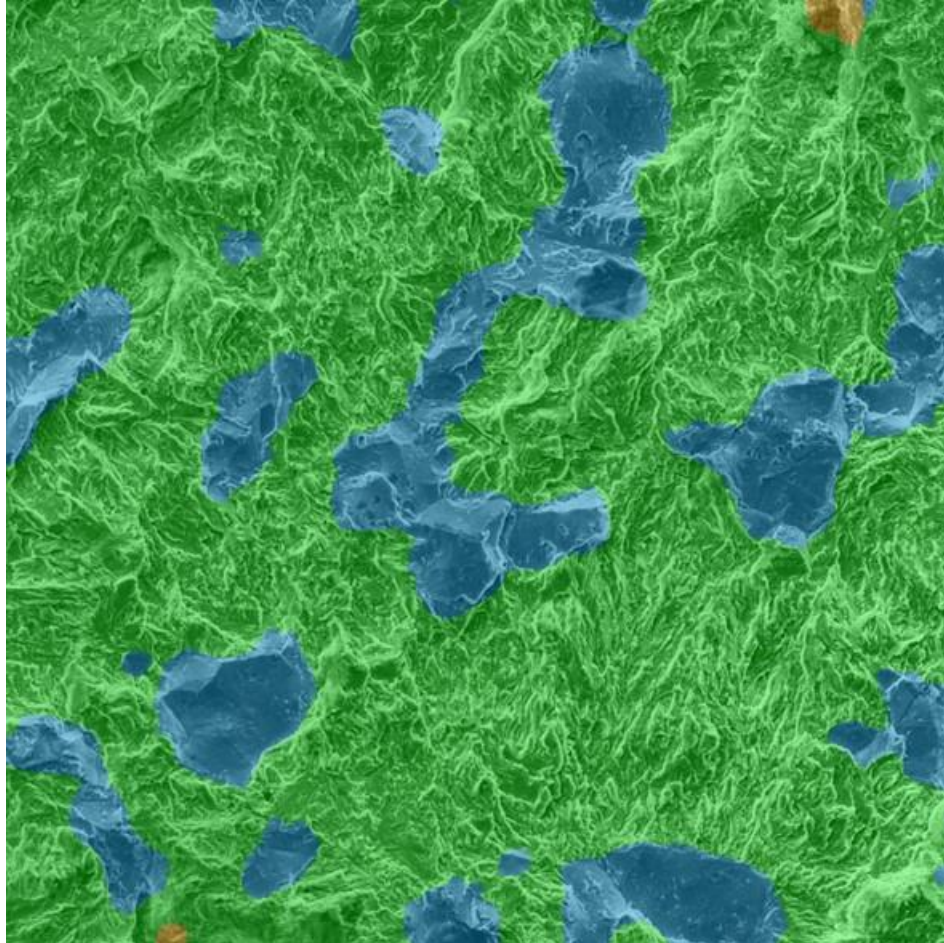
Further results



	Dimple surface (honeycombs)
	Cleavage areas
	Grain boundaries
	Facets
	Not allocated

Results

Further results



	Dimple surface (honeycombs)
	Cleavage areas
	Grain boundaries
	Facets
	Not allocated

Fractographic Database (free access)

Fracto DataBase

Fractographic database of the fractography group

https://www.fraktographie.bam.de

FrAkto Graphie

Frakto- Datenbank

- ① Introduction
- ① What's new?
- ① Topics
- ① Info center
- ① data center

AG fractography

- ① Introduction
- ① Meetings / lectures
- ① Fracto_Graphie
- ① I fracto
- ① literature
- DVM - DGM - BAM

Contact

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✉ fraktographie@bam.de

last change: 23.7.2021

➤ **DVM**
DVM German Association for Materials Research and Testing eV

➤ **DGM**
DGM German Society for Material Science eV

➤ **BAM**
BAM Federal Institute for Materials Research and Testing
Sicherheit in Technik und Chemie

Data center

This is the central menu of the Frakto database. Depending on the access rights, you will find functions for search, input, review and administration here.

selection

Predefined selection and listing of data sets (fractography cases)

- **Material menu** : Step-by-step table selection of fractography cases
- **all materials** : table of all fractography cases sorted by materials
- **all fractography cases** : List of all fractography cases alphabetically case numbers

search

Find records by entering search terms. So far, you can only search for the beginning of a word, entering placeholders such as * or ? can not.

- **Fractography Case - Case Number**
- **Image - microscopic characteristic**
- **Image - macroscopic characteristics**

Data maintenance (requires author rights)

Creation of new fractography cases and associated image data sets as well as review of new data sets depending on authorization.

- **new fractography case**
- **new picture**
- **all files to be shared**
- **all shared images**

Administration (requires admin rights)

User administration with assignment of authorizations. Attention: Users must be set up by the BAM admin outside of the Frakto DB.

Fracto DataBase

Fraktographische Datenbank der AG Fraktographie

https://www.fraktographie.bam.de

FrAkto Graphie

Info-Zentrum

löschen bearbeiten

Frakto-Datenbank

- ① Einführung
- ① Was ist neu?
- ① Datenbank

AG Fraktographie

- ① Einführung
- ① Treffen/Vorträge
- ① Frakto-Symbolik
- DVM / DGM

Kontakt

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☎ +49 30 8104-1512
✉ fraktographie@bam.de

➤ **DVM**
DVM Deutscher Verband für Materialforschung und -prüfung eV

➤ **DGM**
DGM Deutsche Gesellschaft für Materialkunde eV

➤ **BAM**
BAM Bundesanstalt für Materialforschung und -prüfung
Sicherheit in Technik und Chemie
letzte Änderung: 27.3.2020

Fraktographie-Fall

Fall-Nummer: FS038_Kolbenstange

Fallbeschreibung: **Schadensfall**

Bruch einer Kolbenstange

Bruch einer Kolbenstange aus einer Fertigungsanlage. Schwingbruch mit sprödem Restgussbruch. Werkstoff 38MnVS6, Härte ca. 280 HV10.

REM- und Schliff-Bilder von C. Greiner (Brose), Makrofotos und Feldemissions-REM: BAM

Quelle: BAM / C. Greiner (Brose Fahrzeugteile GmbH & Co. KG, Coburg), 2019/2020

Werkstoff

Werkstoffklasse: Metall

Subklasse: Eisenwerkstoff

Werkstoff-Gruppe: Stahl

Werkstoff-Name: 38MnVS6, 1.1303

Betriebs- und prüfbedingungen

Lebensdauer/Standzeit: ca. 12 Mio. Hübe

löschen bearbeiten

Bild

Fall-Nummer: FS038_Kolbenstange

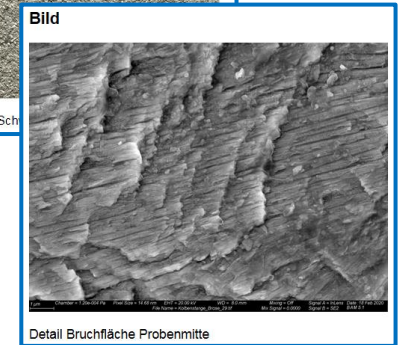
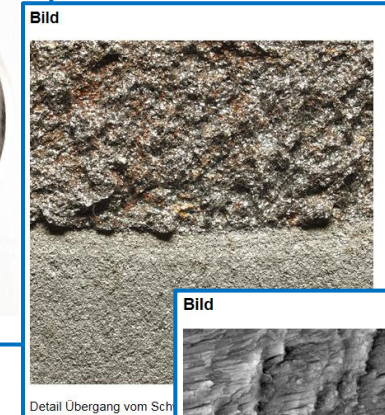
Bild-Art: globale Übersicht

Aufnahmetechnik: Makrofoto



Contents (9/2022):

- > 380 data sets
- > 4.200 images



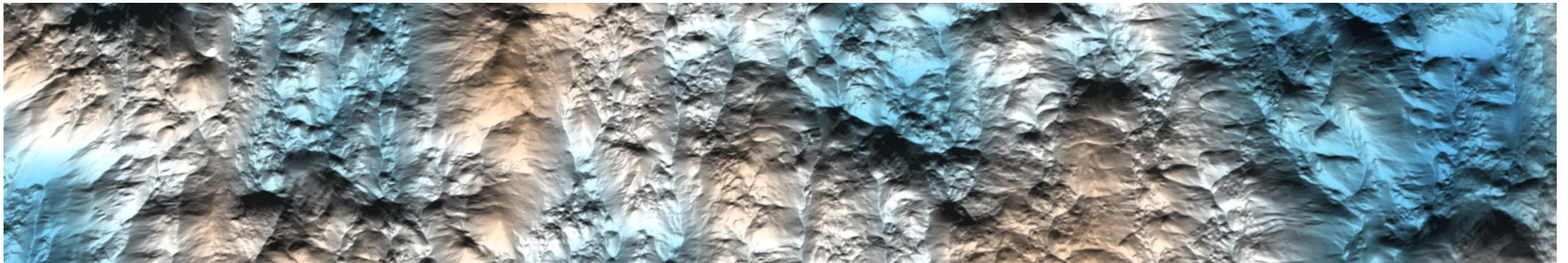
www.fraktographie.bam.de

request password: please email

fraktographie@bam.de

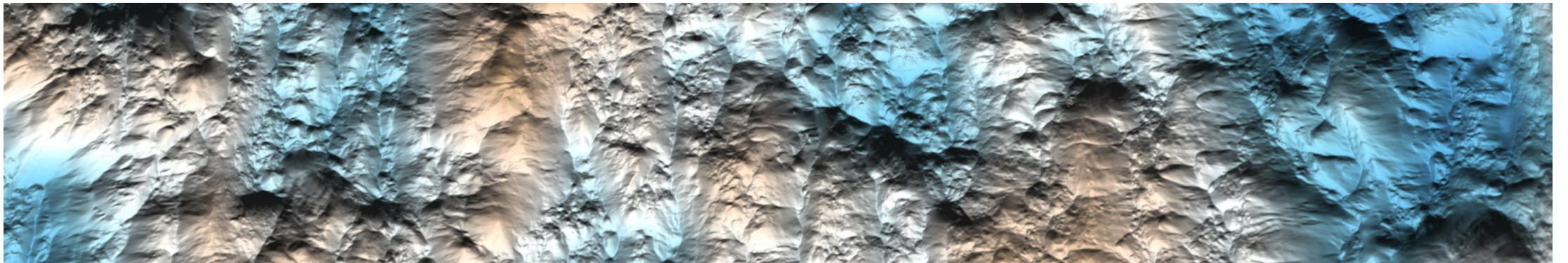
Summary

- // Software prototype ready for quantitative fractography
- // 1st round robin test for generation of training data set
- // Classifier and training data enhanced with topographic data
- // 2nd round robin test with software prototype
- // Promising results for SE images in combination with BSE data and height maps
- // Enhanced fractography database



Outlook

- // Integration of prediction in SEM software (live pre-classification)
- // Interface to fractography database
- // Enhanced training data management (growing knowledge)
- // Further development of fractography software (market release)



Thank you!



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