Computer-assisted Analysis of Asbestos Samples

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Supported by Bianca Gasse, Dennis Kaiser and Markus Mattenklott

BAuA – Federal Institute for Occupational Safety and Health

Unit 4.I.5 „Materials and Particulate Hazardous Substances "

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baua:

Activities of BAuA Unit 4.I.5 related to Fibres

Research

HARMLESS **(EU),** ***Macramé*** **(EU),** ***POLYRISK*** **(EU),**
NanoHarmony **(EU),** ***Gov4Nano*** **(EU),** ***NanoIndEx*** **(EU),**
Nanodevice **(EU),** ***NanoValid*** **(EU),** ***NANoREG*** **(EU),**
AsbestosDetect **(DGUV),** ***Nanofaser-Messstrategie*** **(DGUV),**
InnoMatLife **(BMBF),** ***nanoGEM*** **(BMBF),** ***nanoGravur*** **(BMBF),**
ELSE **(BMBF),** ***CarboLifeCycle*** **(BMBF),** ***CarboSafe*** **(BMBF),**
CarboBreak **(BMBF),** ***CEN-NOAA*** **(CEN),** ***EMMI*** **(UBA),** ***EFA*** **(BMUB),**
MOSIS **(BAuA/PTB),** ***OPC*** **(BAuA/IUTA)**

Regulation

TRGS 527 – Seite 1 von 31 *(Fassung 20.2.2020)*

GMBl 2020 S. 102-118 [Nr. 6] (v. 19.2.2020)

Technische Regeln für Gefahrstoffe	**Tätigkeiten mit Nanomaterialien**	**TRGS 527**

OECD
BETTER POLICIES FOR BETTER LIVES

Test Guideline No. 125

Nanomaterial Particle Size and Size Distribution of Nanomaterials

Development of Testing Methods

atmosphere

[Atmosphere **2020**, 11, 1254; doi:10.3390/atmos11111254]

MDPI

Article

A Practicable Measurement Strategy for Compliance Checking Number Concentrations of Airborne Nano- and Microscale Fibers

Asmus Meyer-Plath *, Daphne Bäger, Nico Dziurowitz, Doris Perseke, Barbara Katrin Simonow, Carmen Thim, Daniela Wenzlaff and Sabine Plitzko

Partikel

Messung nano- und mikroskaliger faserförmiger Materialien an Arbeitsplätzen (Teil 1)

S. Plitzko, A. Meyer-Plath, N. Dziurowitz, B. Simonow, P. Steinle, M. Mattenklott

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78 (2018) Nr. 5 - Mai — Gefahrstoffe - Reinhaltung der Luft

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Partikel

Messung nano- und mikroskaliger faserförmiger Materialien an Arbeitsplätzen – Teil 2

S. Plitzko, A. Meyer-Plath, N. Dziurowitz, B. Simonow, P. Steinle, M. Mattenklott

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Requirements
for Computer-assisted Analysis of Filter Samples

1
- Software-controllable SEM
- Measurement convention for reliably detectable image content
- Software for automated object recognition and contour tracing
- Algorithms for morphological classification of recognised objects

2
- Software-controllable EDS system
- Measurement convention for reliably quantifiable EDS spectra
- Software for automated EDS-based elemental quantification
- Algorithms for spectral classification of recognised objects

3
- Automated execution of measurement guidelines VDI 3492, DGUV 213-546, …
- Database for analysis results
- Result compilation for final assessment by compenent personnel

4
- Validation experiments and participation in round robin tests

Software-controllable SEMs for Filter Sample Imaging

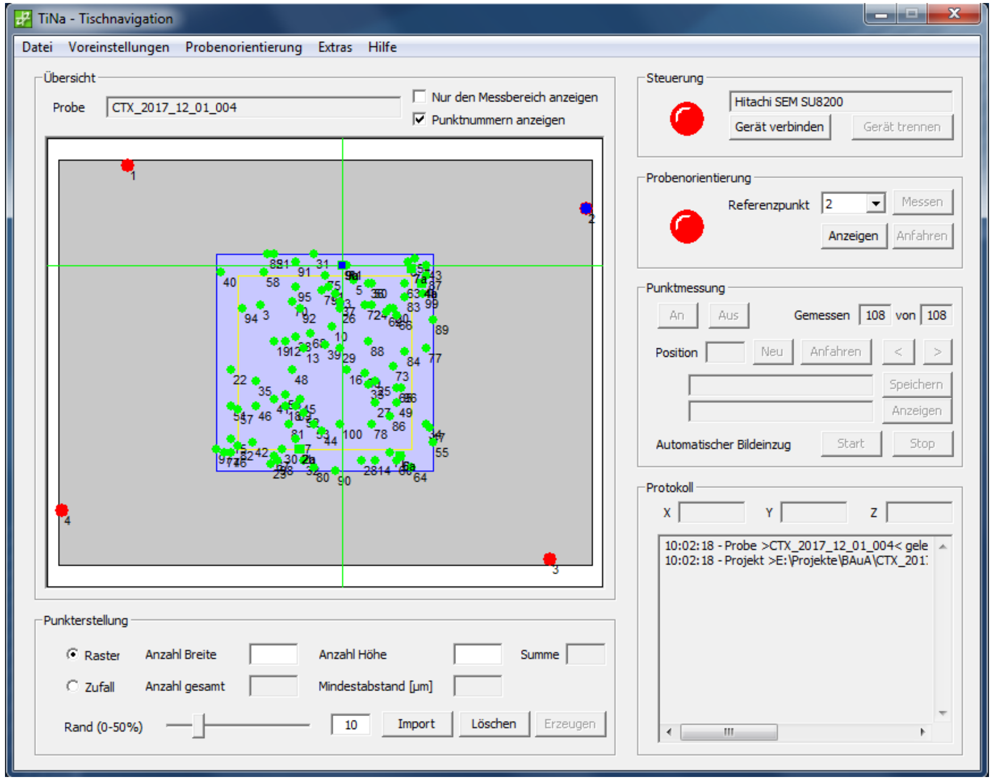
- **<u>Currently</u>, our Software can control SEMs**
  - **by Hitachi**
  - **Equipped with a DISS5-Interface by Point Electronic GmbH**

  provided they offer a working <u>autofocus</u>
- **<u>Planned</u> are to control SEMs by**
  - **Thermo-Fisher (Phenom) and Zeiss**

Hitachi SU5000
Hitachi SU8x00

Phenom XL
https://www.thermofisher.com/de/de/home/electron-microscopy

TiNa

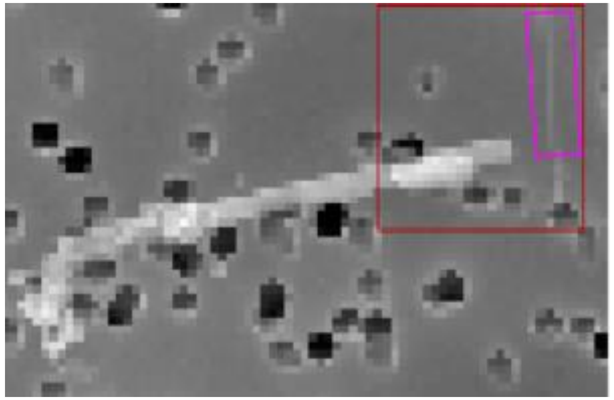


Measurement Convention for Reliably Detectable Digitized Content

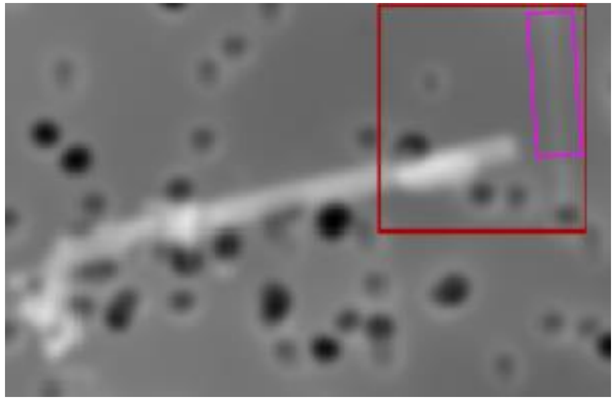
Point Resolution, sharpness and dynamic range of images must be sufficient for offline fibre recognition!

Recommendation of OECD TG 125: 25% error on diameter: 4 pixels per 200 nm for PCM-analogue recognisability

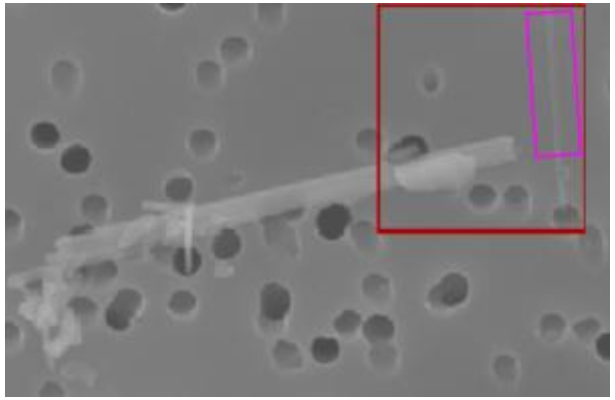
low point resolution: 100 nm

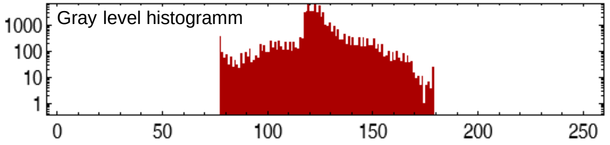


low image sharpness

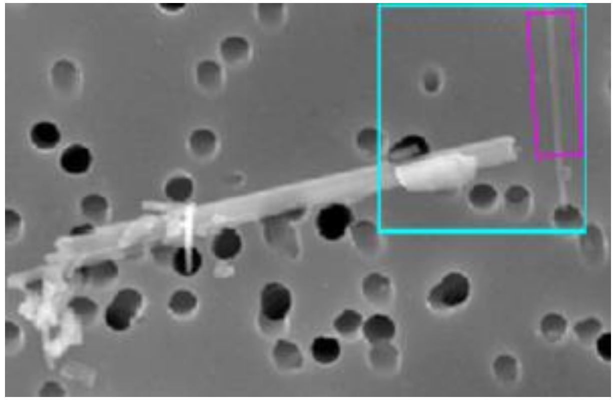


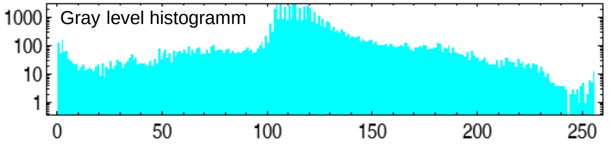
low dynamic range





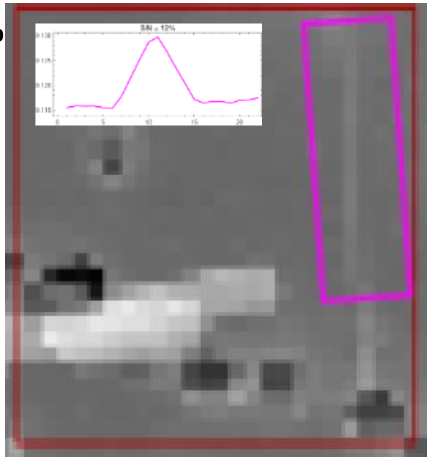
high resolution, sharpness and dynamic





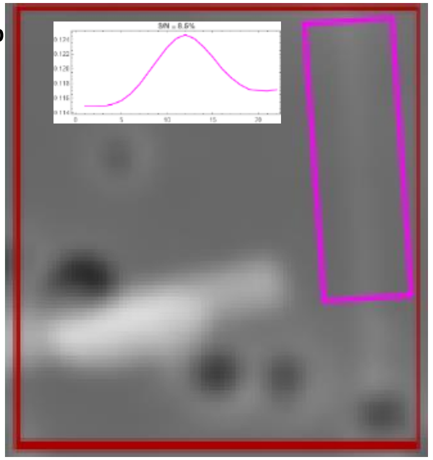
non-interactively adjusted resolution

S/N=12%

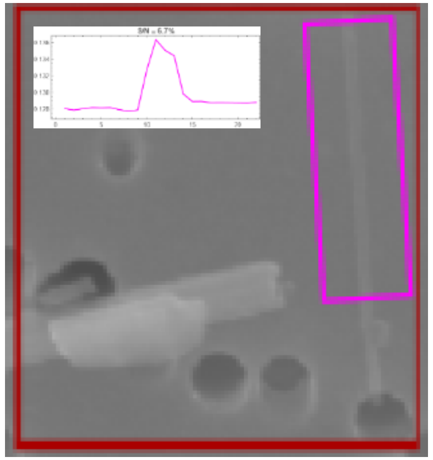


non-interactively adjusted sharpness

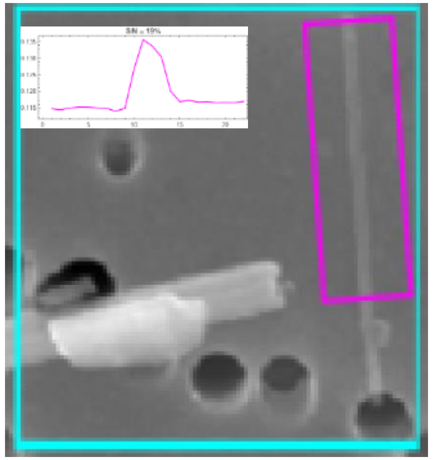
S/N=8.5%



S/N=6.7%



S/N=19%



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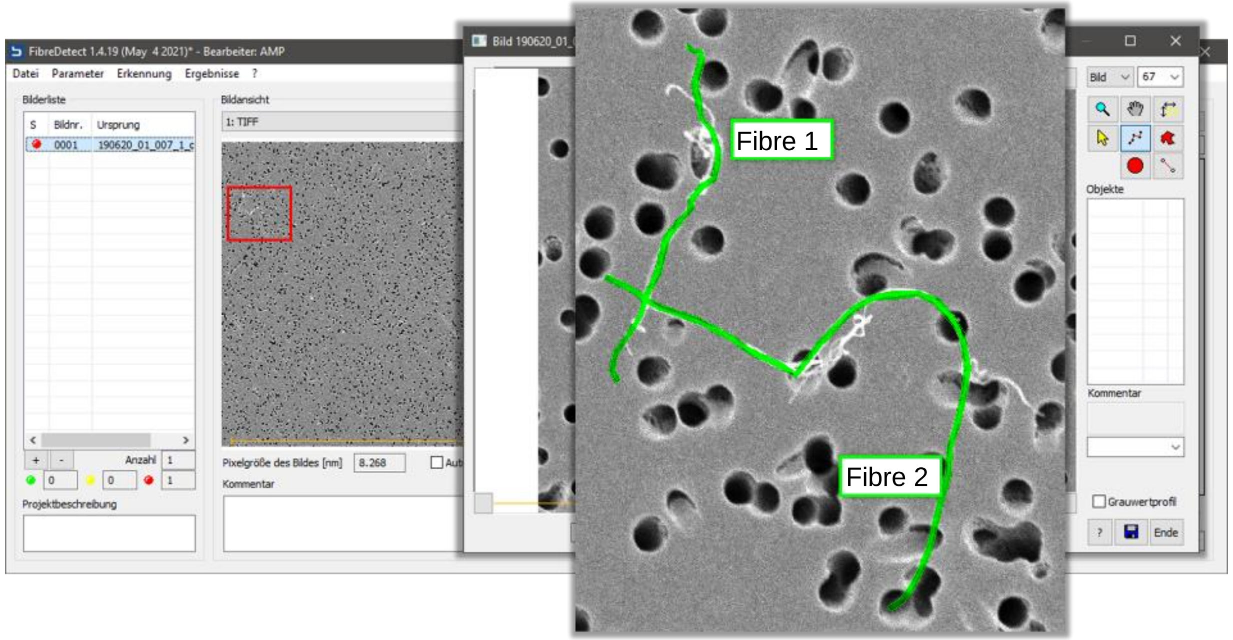
Visually localised Fibres as Trainings Data for Neural Nets

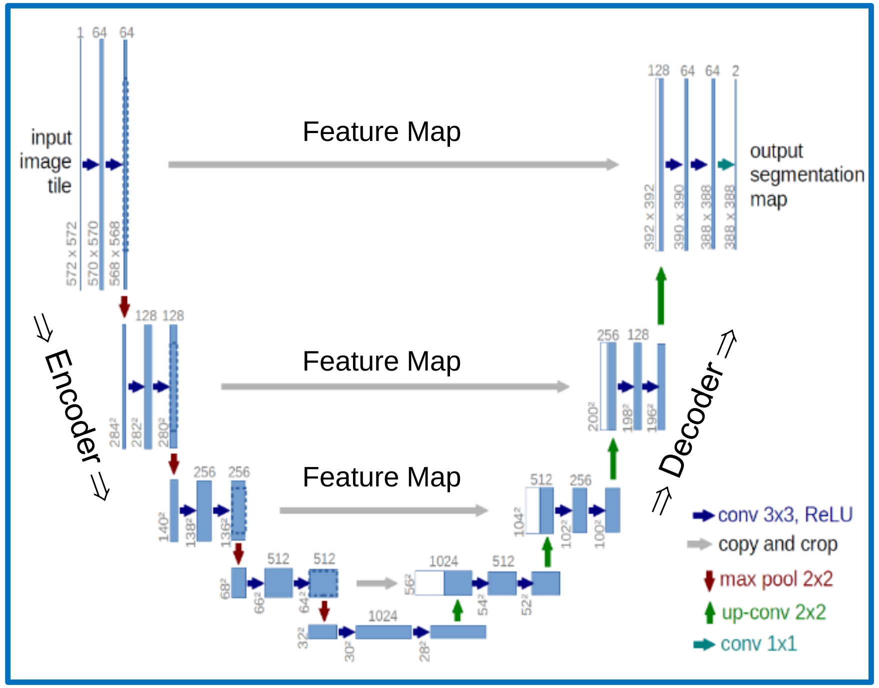
- **We manually marked the <u>Position and Contour</u> of many thousand Fibres using our Analysis Software**



- **The "annotated" Images were used to train Artificial Neural Nets (ANN)**

- **We use ANNs with so-called U-Net Architecture and <u>train</u> them with about <u>20 Gigapixels of annotated image data</u>.**

Artificial Neural Nets (ANN)

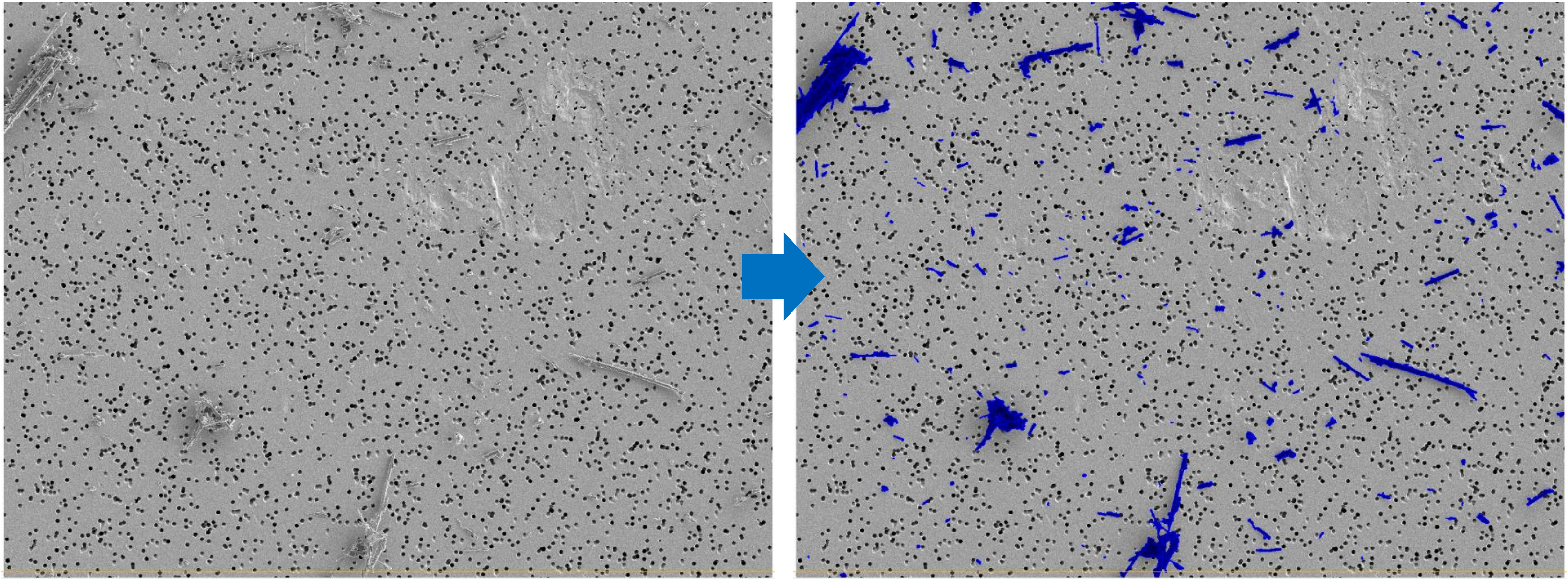


Optimisation of Convolution Kernels while preserving the Feature Maps

[O. Ronneberger et al, 2015]

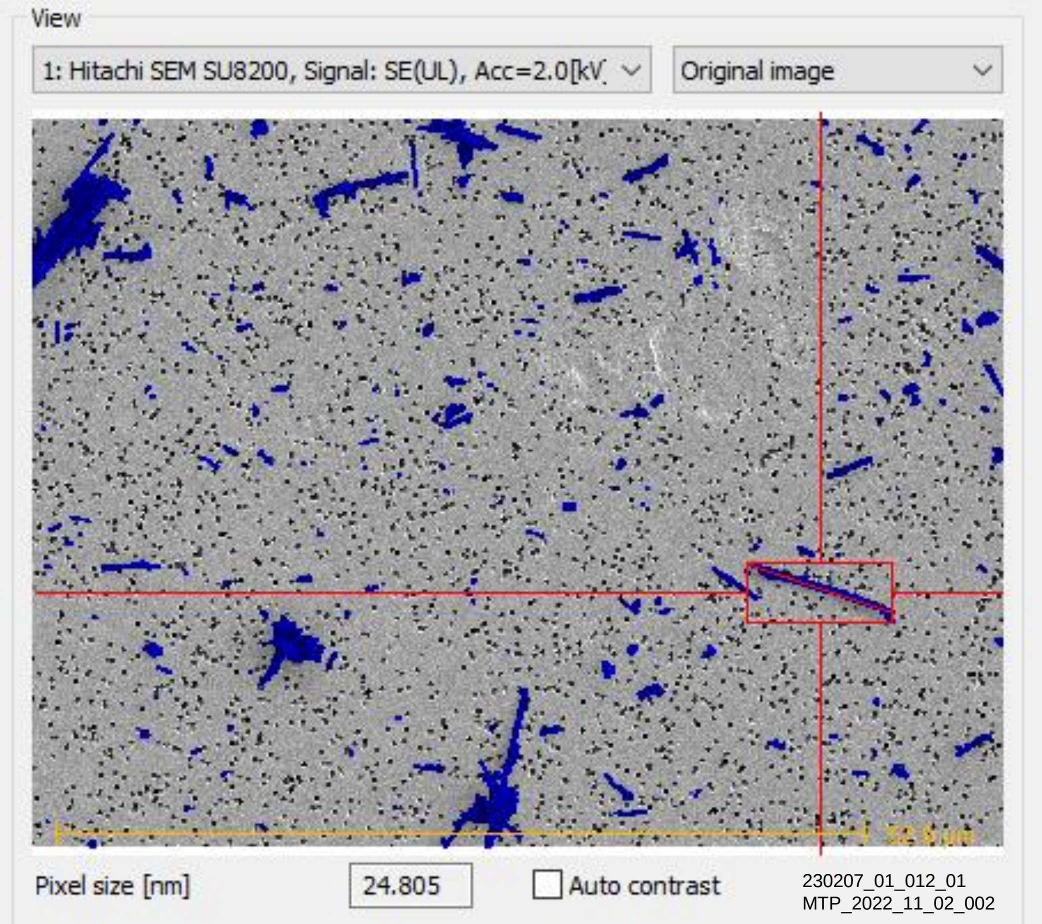
Reliable Neural Nets for Fibre Recognition

- **Traditionally:** Human Neural Net (Visual Cortex)
- **New:** Artificial Neural Net (Convolutional NN)



Algorithmic Measurement and Classification of Morphology

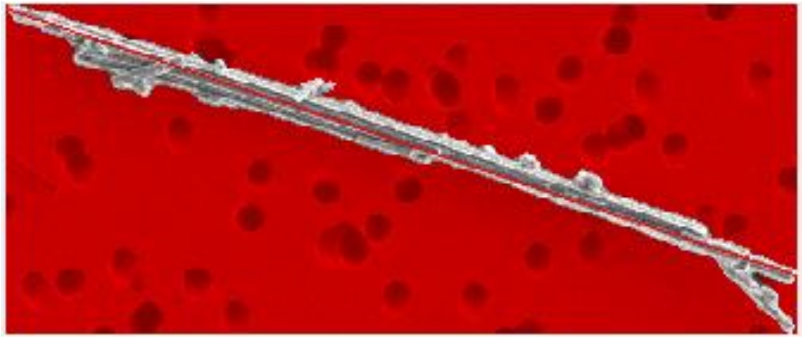
Pixel-based calculation of rectified fibre length and mean fibre width



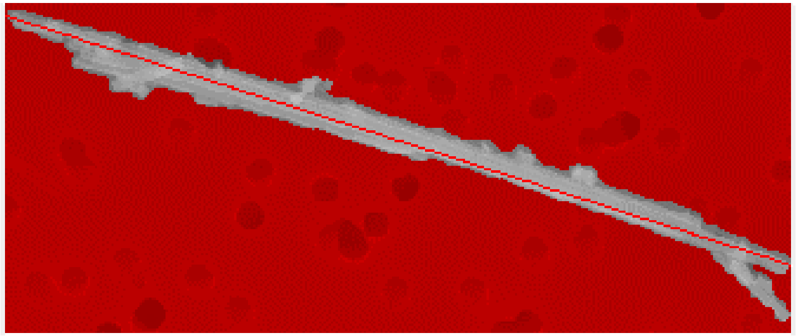
AsbestosDetect

Object recognized as WHO Fibre

High resolution SEM image at 2 kV



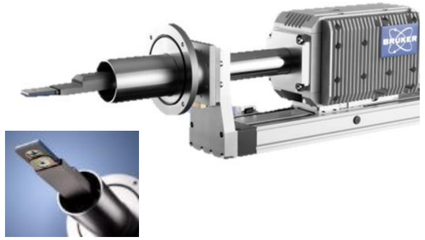
SEM image at 12 kV



Software-controllable EDS System for Elemental Analysis

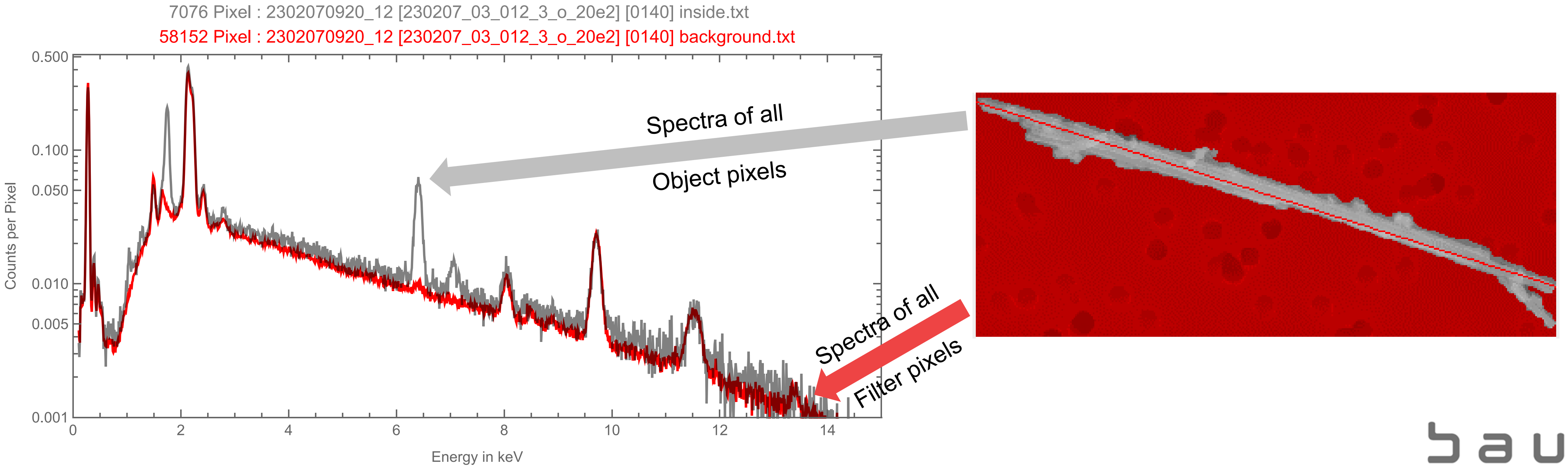
- **Currently** we can control **EDS systems by Bruker**
- **Planned** is to control Thermo-Fisher (**Phenom**) and **Oxford EDS Systems**.

Bruker XFlash



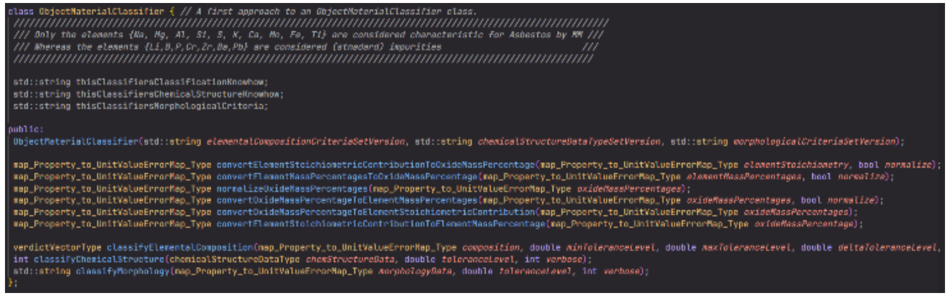
Bruker FlatQUAD

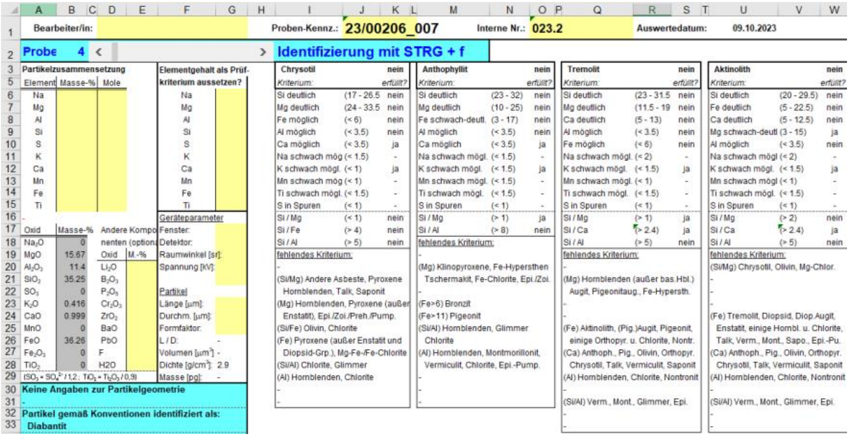
- **EDS Mappings** enable us to analyse a fibre in its filter environment



EDS Classification by Algorithms and Artificial Neural Nets

- **Algorithm: Convention on EDS Element Concentration Ranges**
  - C++-Module (BAuA)
  - Excel (M.M.)

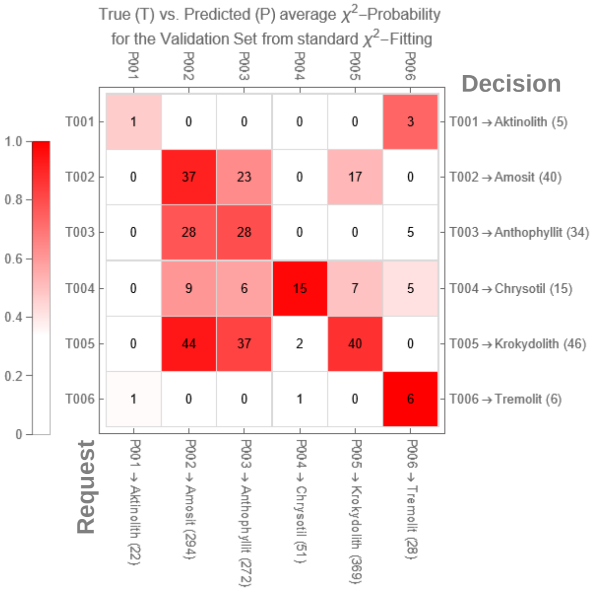




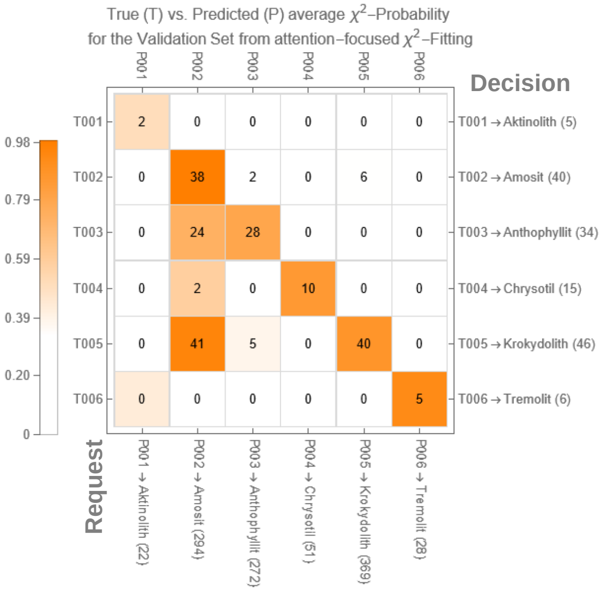
- **ANN: Direct Interpretation of raw EDS Spectra**

Matrices of Confusion

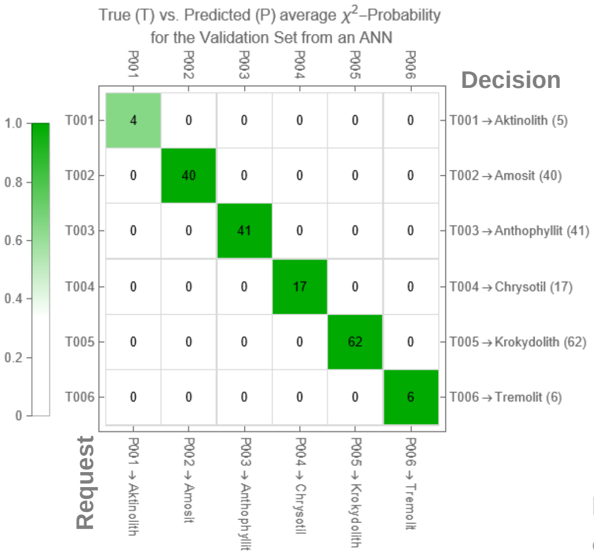
χ^2-Fit classical Approach



χ^2-Fit with Peak Focus



Artificial Neural Net



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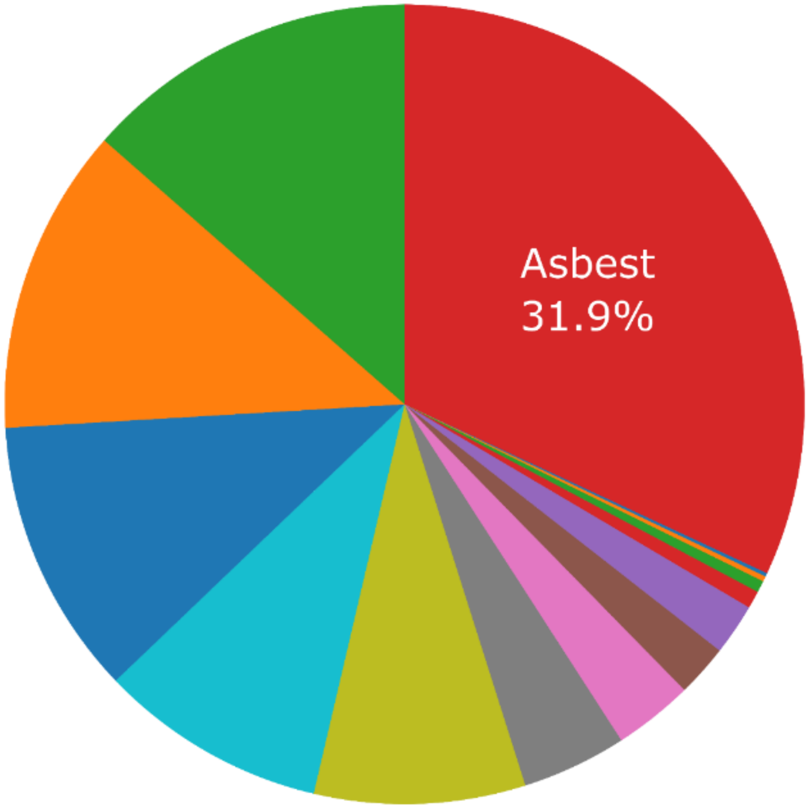
Requirements: Microscope Control • Images • Recognition • Morphology • EDS • Interpretation

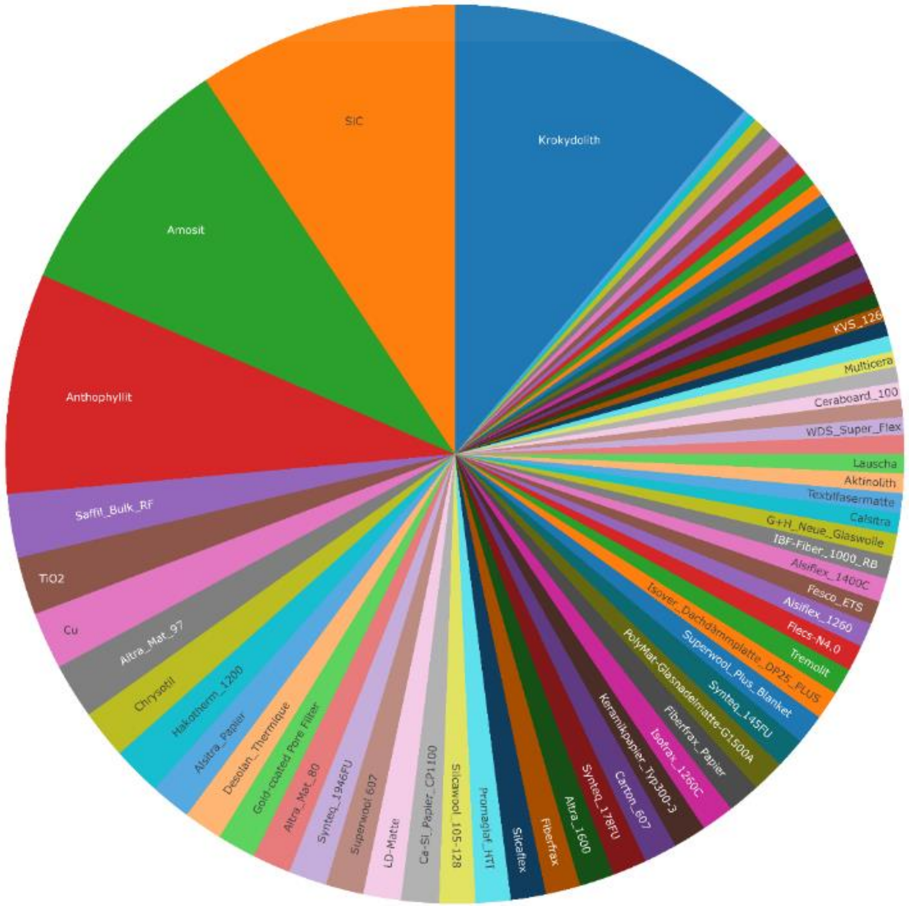
Training of an ANN for the Classification of EDS Spectra

Fibre Materials from 14 Categories



- Asbestos
- Silicon/Silica Fibres
- High-temperature Glass Fibres
- Aluminium Silicate Fibres
- Old Mineral Wools
- Alumina Fibres
- Micro Glass Fibres
- New Mineral Wools
- Titania Fibres
- Copper Fibres
- Textile Fibre Mats
- Whisker
- Glass Bead Splinters
- Organic Fibres

75 Fibre Materials

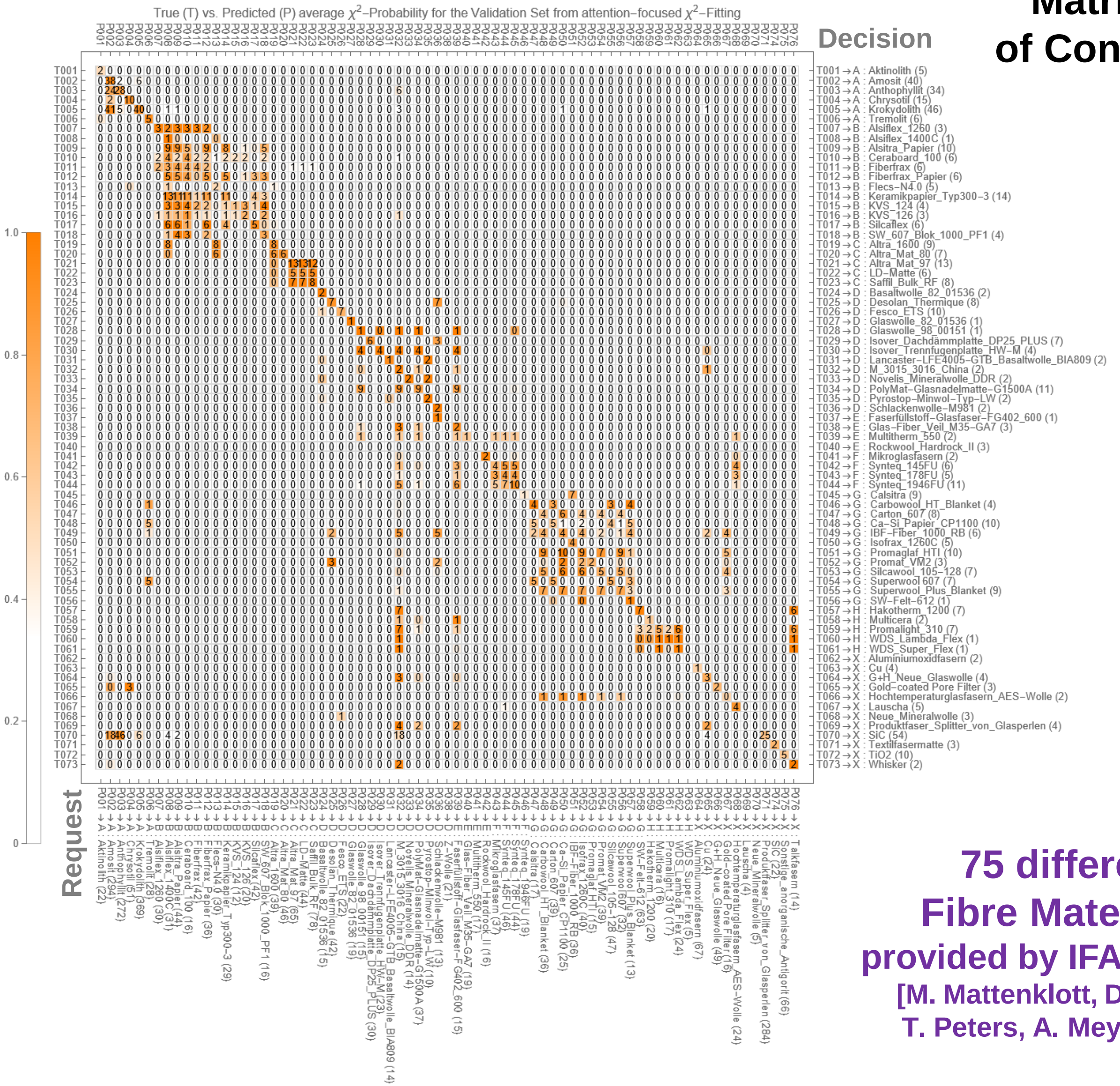


ANN Training using about 4.400 EDS Spectra Provided by IFA and BAuA

Requirements: Microscope Control • Images • Recognition • Morphology • EDS • Interpretation

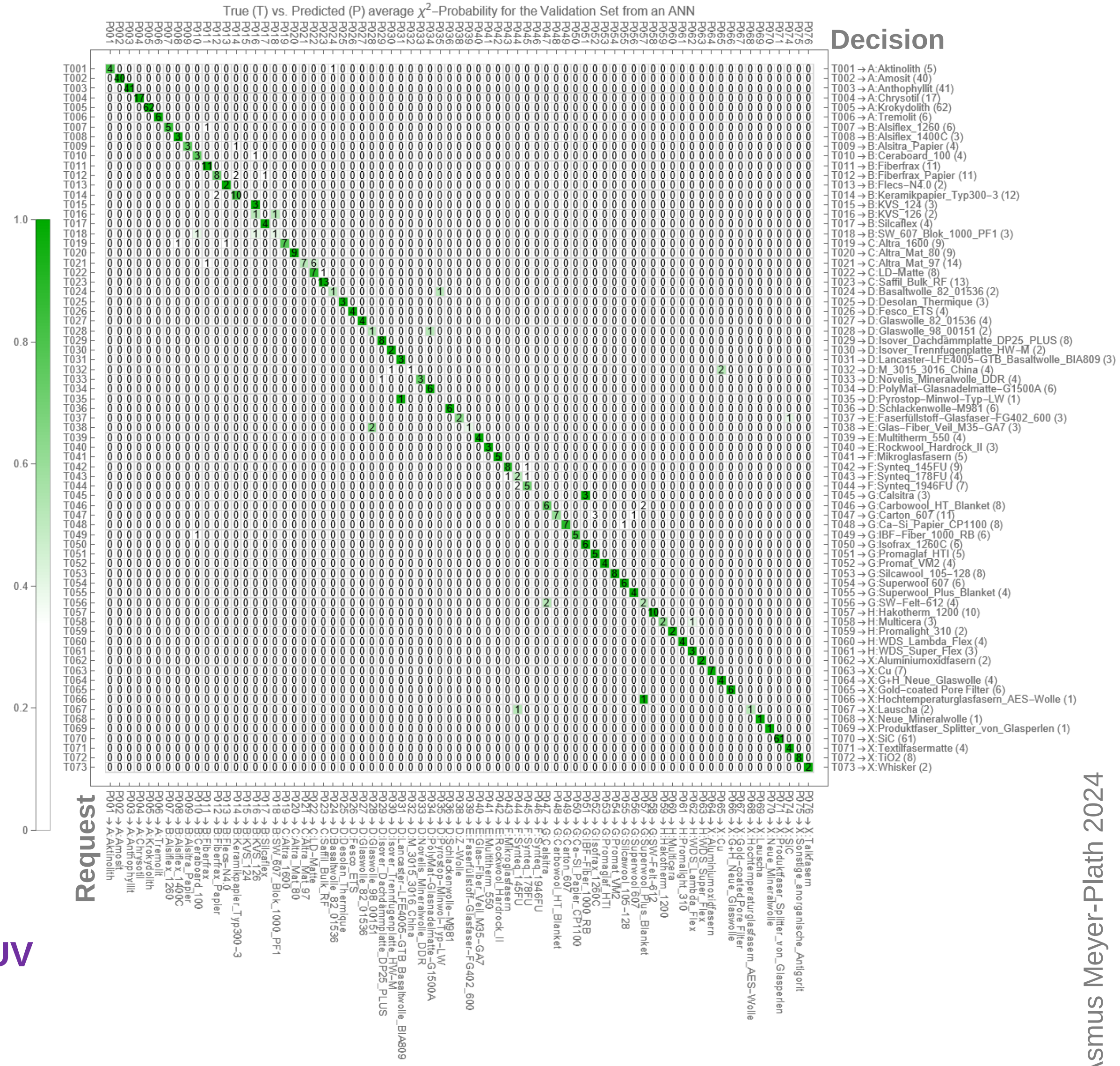
ANN-based Classification of raw EDS Spectra

χ^2-Fit mit Peakfokus



Matrices of Confusion

Artificial Neural Net



75 different Fibre Materials provided by IFA of DGUV

[M. Mattenklott, D. Kaiser, T. Peters, A. Meyer-Plath]

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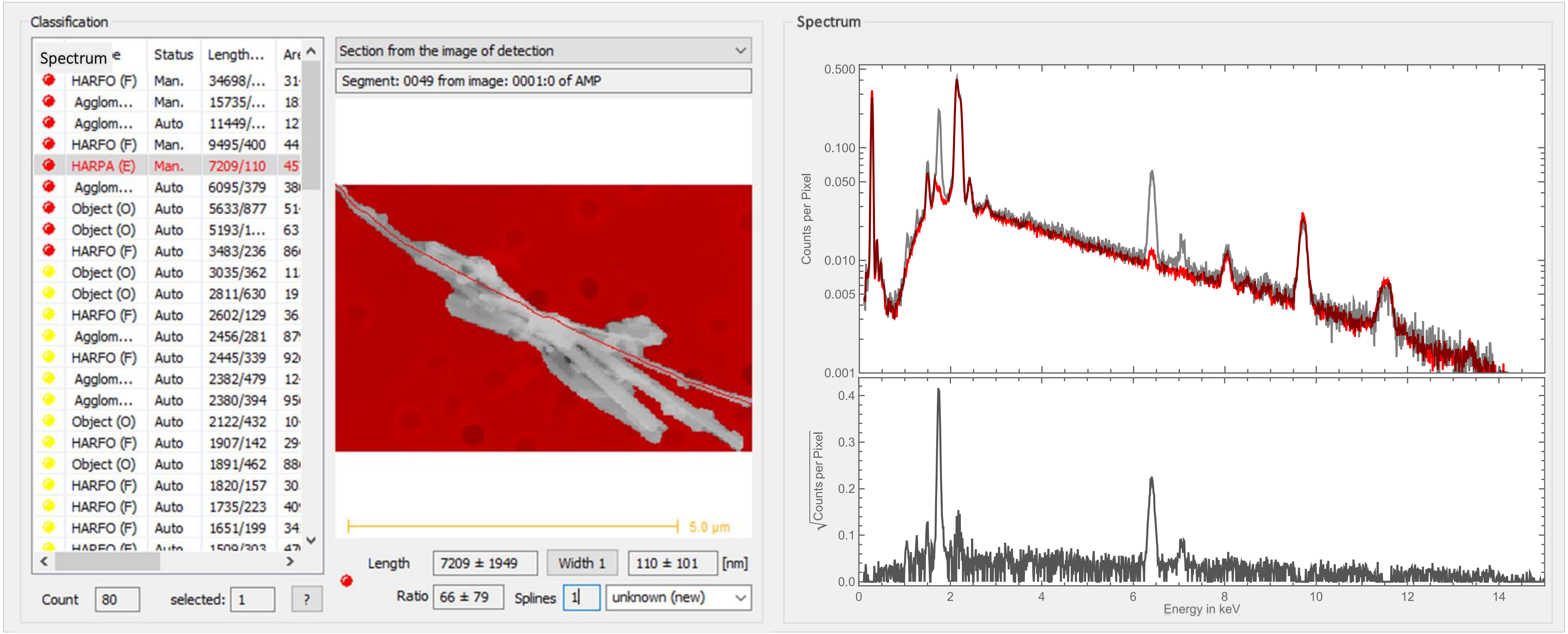
Compilation of Results and Assessment by Competent Personnel

It must be possible to overrule decisions made automatically at any time in a documented manner.

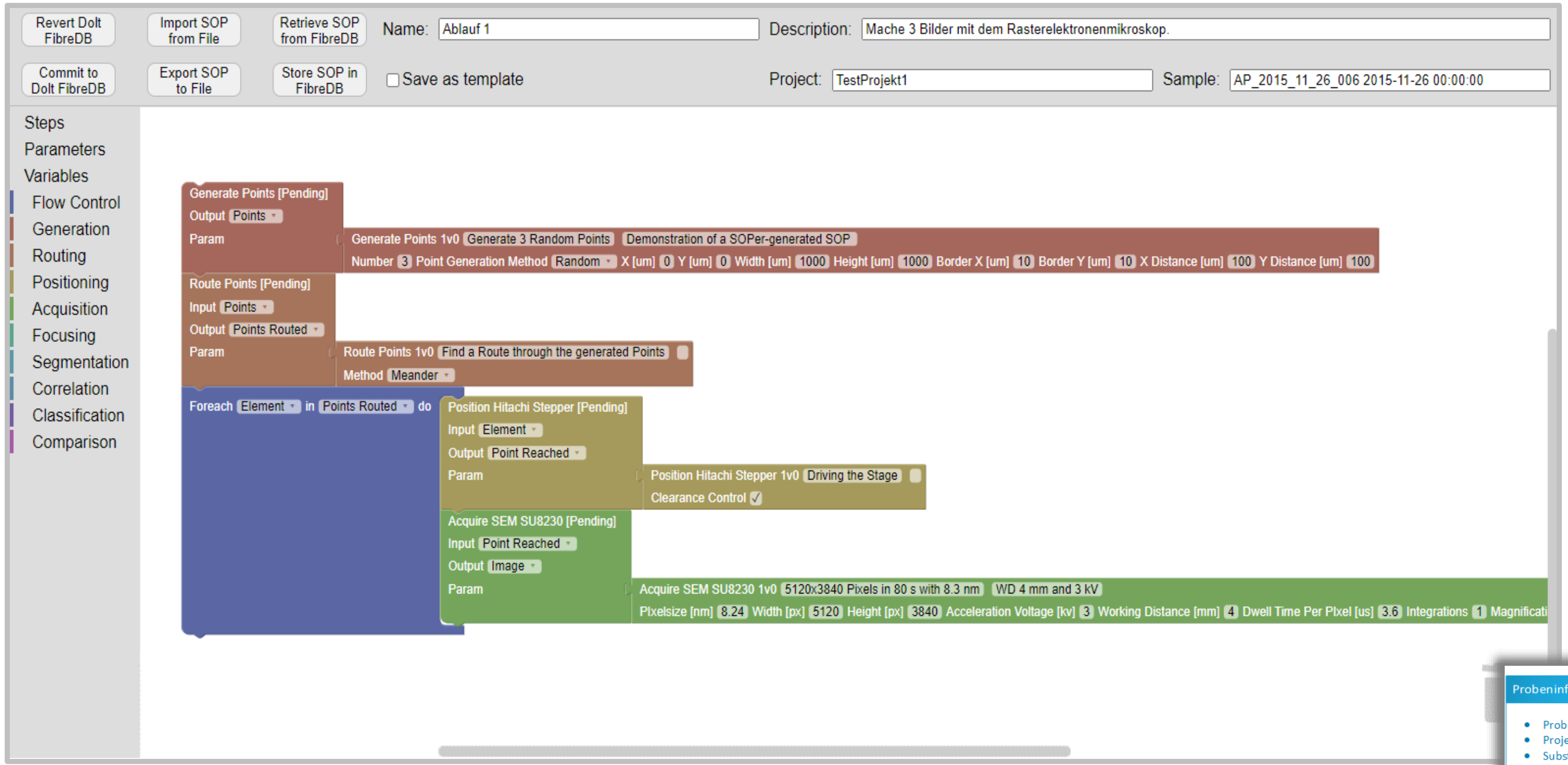
Object List ***Object Viewer*** ***Spectrum Viewer***



AsbestosDetect

Requirements: Microscope Control • Images • Recognition • Morphology • EDS • Interpretation • Automation

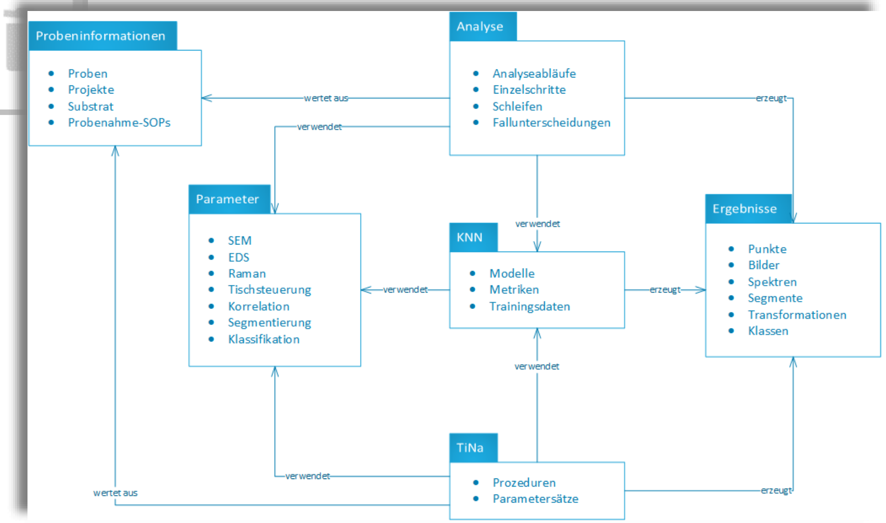
Automated Execution of Measurement Guidelines and Data Handling



SOPer

Editor for the definition of analysis procedures

Fibre Hub Database



- **Automated execution of measurement guidelines**
  e.g. VDI 3492, DGUV 213-546, …
- **Automated data handling and storage in the *Fibre Hub* database**

Acceptance of computer-assisted Asbestos measurements

- Documentation of all data used for ANN training
  ⇒ All trainings data, training history and ANN variants stored in the *Fibre Hub* database

- Definition of analysis guidelines as algorithms
  ⇒ All analysis guidelines are provided as templates by the *Fibre Hub*

- Relational storage of all results generated during analysis in the *Fibre Hub*
  ⇒ Integrated quality management

- Validation experiments
  - Human vs. artificial intelligence
  - Participation in round robin tests and lab intercomparisons
    ⇒ Results made available through the *Fibre Hub*

- Optimisation of the ANNs by using round robin test results as ANN performance reference

- Computer assistance but human experts as final decision-making authority

Perspective

- **Welcome**: Development partnerships for additional hardware combinations
- **Welcome**: Participation in lab intercomparisons and round robin tests
- **Planned**: Provision of the "*AsbestosDetect*" Software by BAuA
- **Planned**: Provision of the *Fibre Hub* database on the Website of BAuA

FG 4.I.5

Research funded by UBA, DGUV, BAuA

Thank You !

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