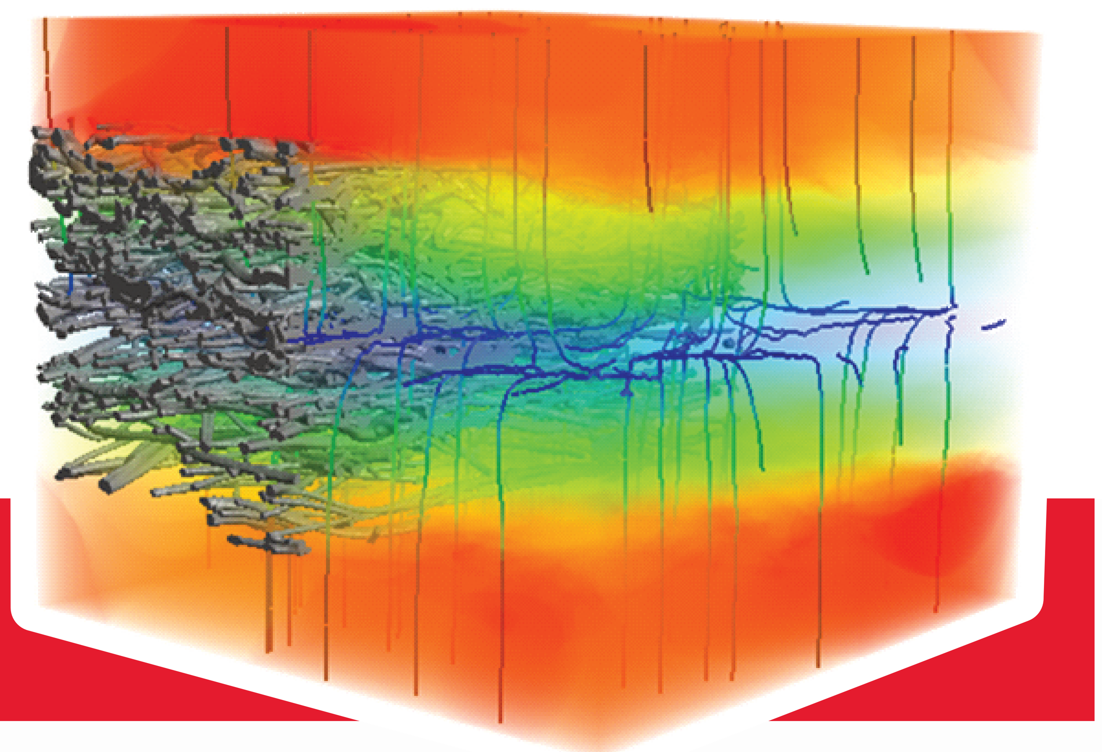
GeoDict
The Digital Material Laboratory

ELEK SIM



Experimental and Numerical Study of Particle Capture in Electret Filters for the Development of an Innovative Simulation Tool

Electret Filter Media Advantages:

- **Improved Filtration Efficiency:** Uses electrostatic charges to attract and trap particles, enhancing filtration beyond physical pore size.
- **Low Pressure Drop & Energy Consumption:** Cost-effective for air filtration by minimizing energy requirements.

Challenges with Electret Filters:

- **Charge Stability:** Maintaining uniformity and charge stability throughout the filter's lifespan.
- **Environmental Factors:** Performance can degrade due to:
  - Humidity
  - Temperature changes
  - Aging
  - Exposure to chemicals

Role of Digitalization:

- **Overcoming Experimental Difficulties**
- **Simulations for Optimization:** Allows for the prediction and optimization of filter performance under various conditions.
- **Cost Reduction:** Helps in reducing material and energy costs
- **Faster Development:** Speeds up the development process and more efficient filter designs.

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Our project partners:

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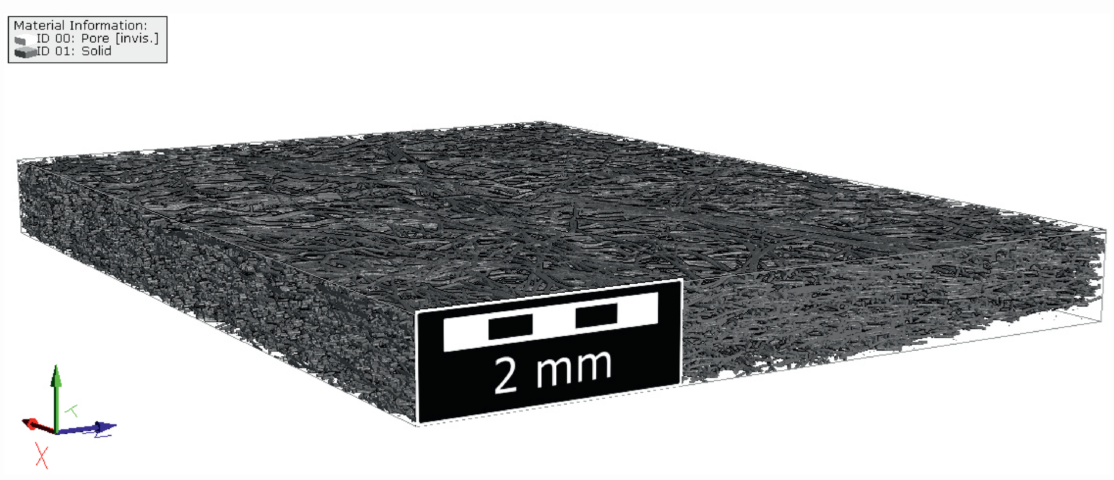
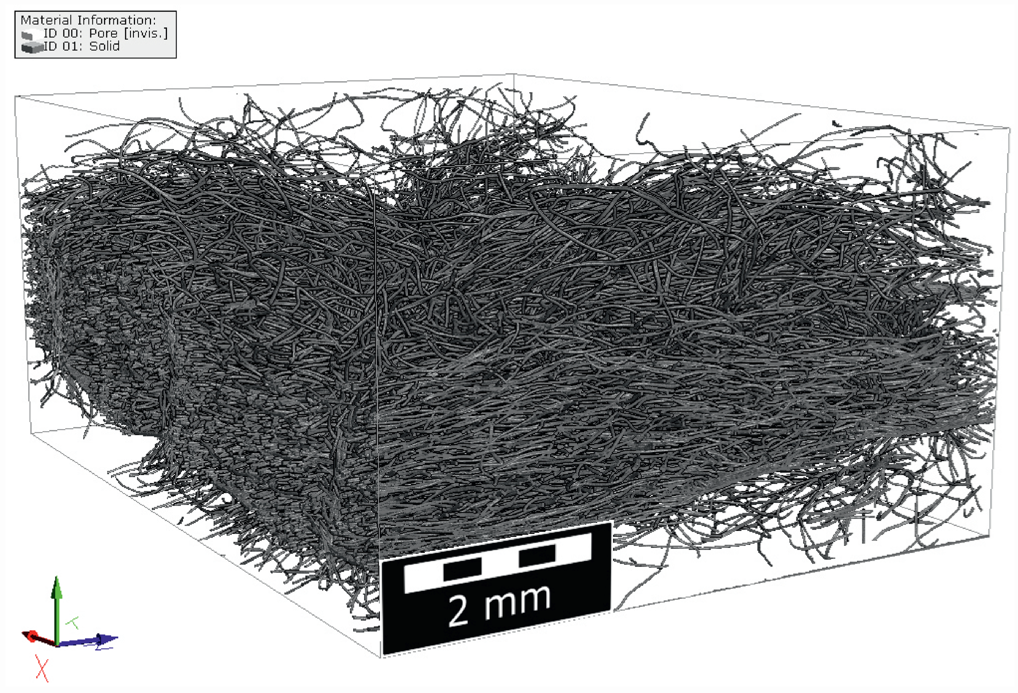
Segmentations were done for two samples named "A" and "E"



Sample **A**

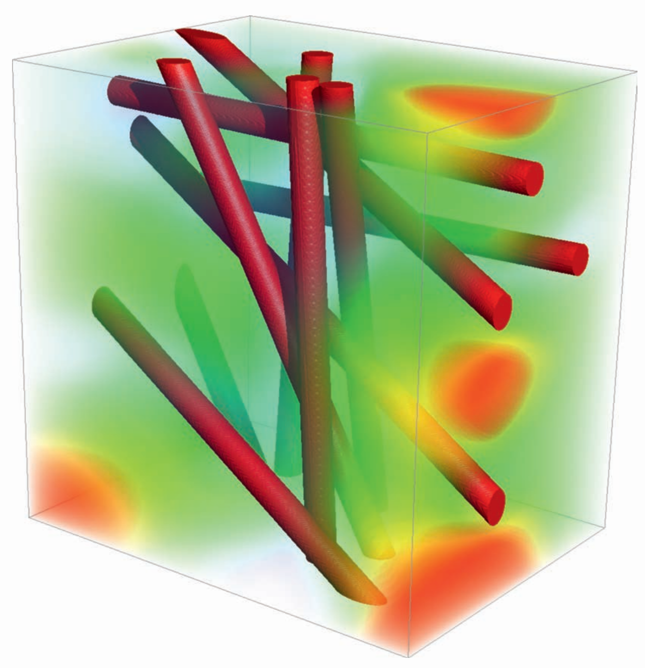


Sample **E**

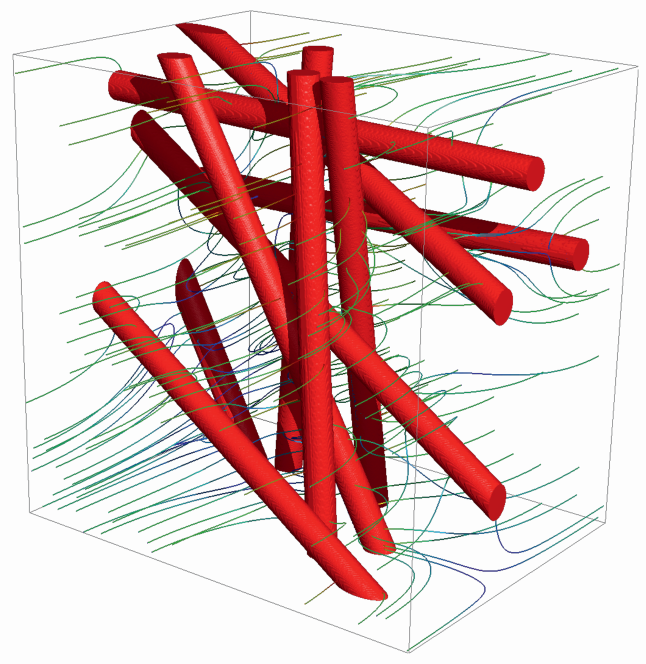
Information about the segmented samples

- Method: Random Forest (AI method)
- Employed image filter: Non-local mean filter
- Segment dimension in voxel (sample **A**): 3416 × 295 × 2451
- Segment dimension in voxel (sample **E**): 3264 × 1456 × 2451
- Voxel length: 3 µm
- Sample **A**: Thickness: 1.04 mm; Fiber diameter: 15 µm
- Sample **E**: Thickness: 1.7–2.4 mm; Fiber diameter: 15–20 µm

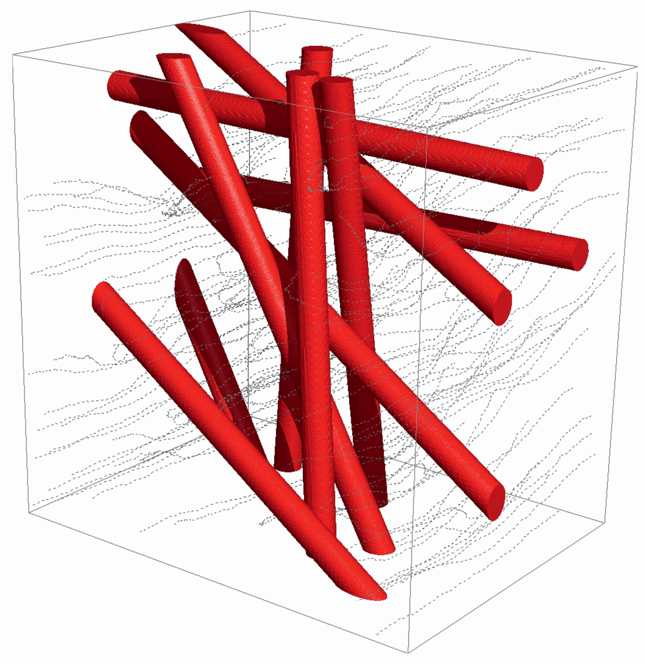
Verification of electrostatic implementation with ANSYS-Fluent[1]



Flow calculation



Determining the electric field

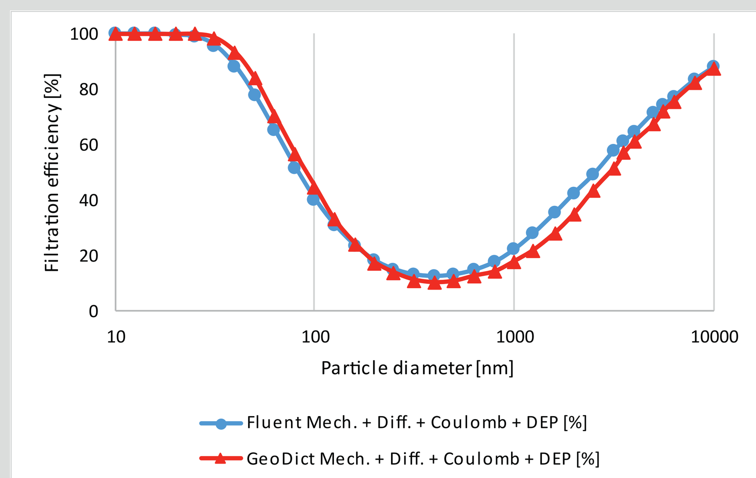


Particle trajectories and separation

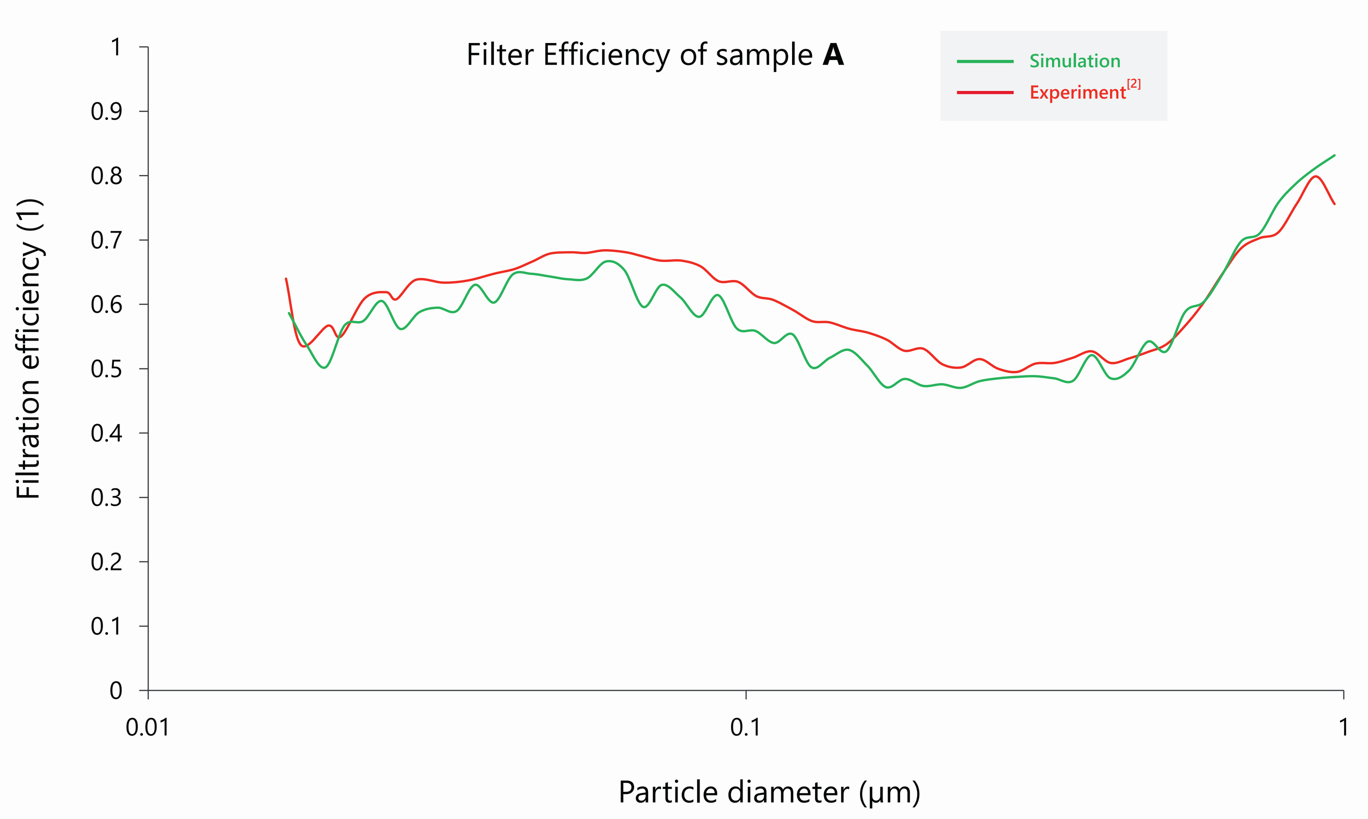
Verification with ANSYS-Fluent

Employed separation mechanism:

- Mechanical
- Diffusion
- Coulomb
- Dielectrophoresis



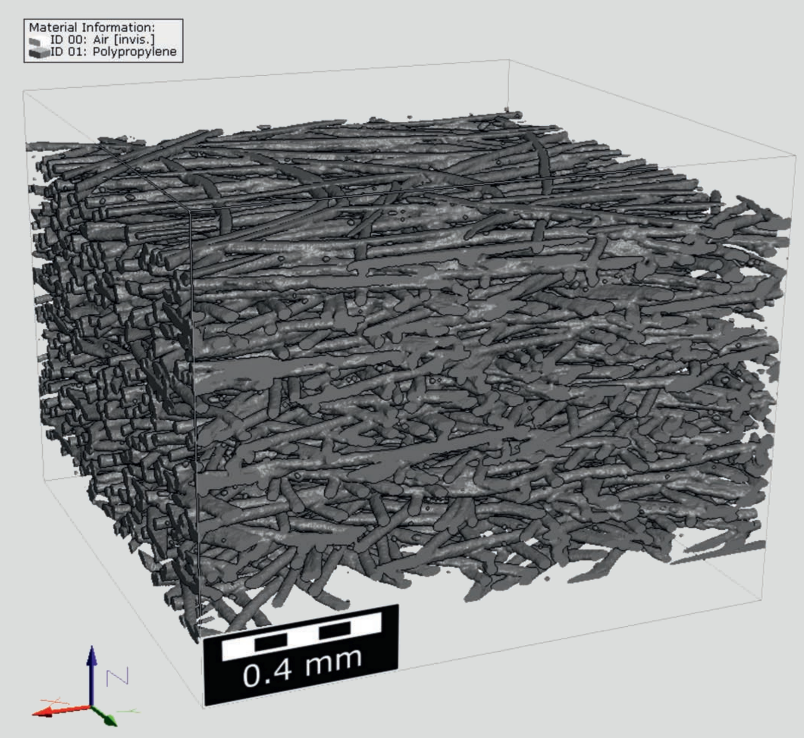
Validation of electret filter media efficiency



Important simulation parameters for sample **A**

- Segment dimension after rescaling: 1024 × 1024 × 790
- Voxel length: 1.5 µm
- Flow motion: Navier-Stokes
- Mean velocity: 0.2 m/s
- Type of the particle charge: Individual per particle type
- Surface charge density: 5e-06 C/m²
- Number of particles per type: 10000
- Dielectrophoresis: Enabled

Part of sample A used in this simulation



Details on the experimental setups are provided in the GIC2025 plenum talk on 12.02.2025 at 10:05, presented by Stefan Schumacher (IUTA)

- The method for calculating particle motion under electrostatic forces is integrated into FilterDict, allowing for various charge distributions.
- Multiple charge distribution possibilities on the fiber surface are supported by reference material measurements.
- A comparison between measurement data and simulation results for initial materials has been completed.
- Future developments focus on identifying the most accurate charge distributions for real systems and simulating filter lifetime with electrostatic effects on particle behavior over time.

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Funding

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References:

[1] ANSYS-Fluent simulations were performed by T. van der Zwaag and T. Engelke from IUTA.

[2] The experimental values are taken from IUTA.

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