# Digital Design and Development of Filter Media for Protective Face Masks


## Validation Study of GeoDict for Filtration

The main route of coronavirus infections during the SARS-CoV-2 pandemic was through airborne particles, i.e., aerosols emitted while breathing, coughing, or sneezing. Wearing a facial mask drastically reduces the risk of infection. Therefor facial masks need to offer a high level of protection, while still allowing to breath easily. This challenge is driven by two major factors:

- ensure a **high filtration efficiency**
- while maintaining a **low pressure drop**.

This validation study was conducted in collaboration with the Heilbronn University of Applied Sciences, in Heilbronn, Germany. The goal was to determine, validate, and optimize the filtration performance of a surgical facial mask. All measurements were carried out by the University of Heilbronn, while the micro-scale simulations and optimizations were performed by Math2Market GmbH using GeoDict.

The complete research article is published in Chemical Engineering & Technology: *https://onlinelibrary.wiley.com/doi/epdf/10.1002/ceat.202200460*

GeoDict
The Digital Material Laboratory

## Digital analysis and performance prediction

## Experimental validation approach

Import, Segmentation, and Fiber Identification

Image processing of the CT scans of a surgical face mask:

A flat sheet of a facial mask is scanned and the µCT images are imported into GeoDict, to obtain a 3D digital representation of the scanned media.

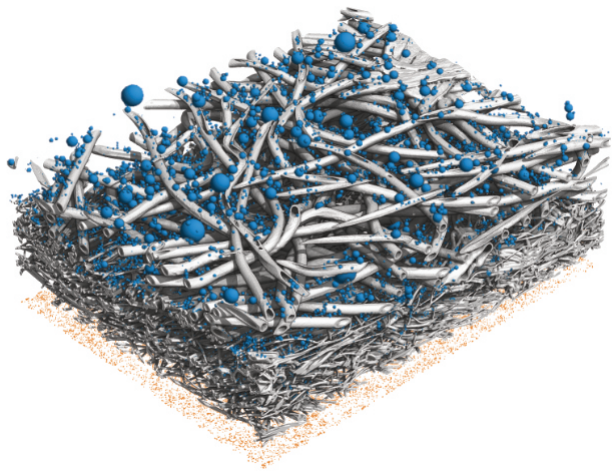
- The µCT scans were provided by the Heilbronn University of Applied Sciences, Germany
- Sample size: 1,2 x 1,2 x 0.7 $mm^3$
- Scan resolution of 400 nm, to resolve fibers down to 1 µm

GeoDict modules used:

- **ImportGeo-Vol** to import, process, and segment the µCT images
- **FiberFind** to obtain geometrical characteristics of the fibers, such as:
  - Fiber diameter
  - Fiber orientation
  - Fiber curliness

**Result:** Digital model of the filter media and its statistical description

Analysis of filter performance



A circular filter sample is cut out of the surgical face mask and pretreated with isopropyl alcohol (IPA). This procedure discharges the fibers, so the separation is exclusively based on mechanical filtration mechanisms. The filter sample is mounted onto a flat material holder and filter efficiency and pressure drop are measured.

- Volume flow: 31.9 $L\ min^{-1}$
- Filter area: 45.4 $cm^2$
- Specific filter velocity: 11.7 $cm\ s^{-1}$, which represents the worst-case application scenario for surgical masks

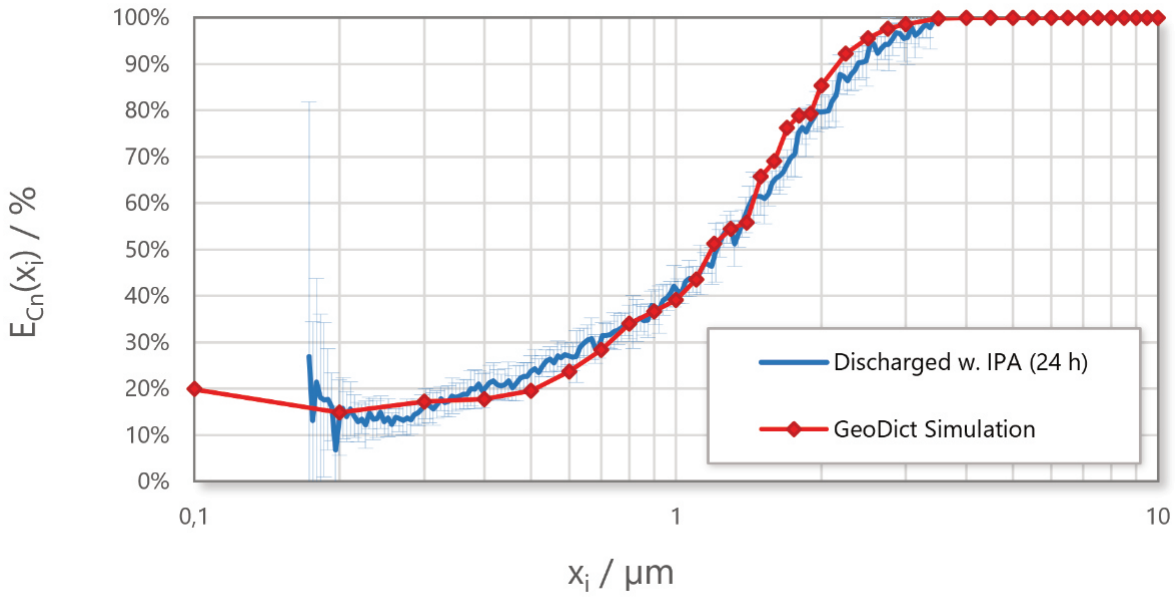
For validation, the same input parameters and particle size distribution used in the experimental setup were applied for the simulation. As the flow in the filter media can be considered laminar, the Stokes equation is solved for the simulation.

GeoDict modules used:

- **FilterDict** to determine initial pressure drop and filtration efficiency

**Result:** Filtration performance relevant parameters, e.g. pressure drop and filter efficiency

## Validation




The pressure drop and the fractional filtration efficiency obtained through the experimental measurements of the face mask are compared to the simulation results obtained using GeoDict.

- The Reynolds number is significantly smaller than 1, given the mean flow velocity of 0.117 $ms^{-1}$, the kinematic viscosity of air 1.7 x $10^{-5}m^2s^{-1}$, and the mean fiber diameter of around 4.52 µm.
- This leads to a creeping, laminar flow, which simplifies the Navier-Stokes equation to the Stokes equation

The filter sample is submerged in IPA for 24h to achieve electrostatic discharge, as defined by the air filtration norm ISO 16890.

The experimental values for the fractional filtration efficiency of the filter media sample and the simulation results obtained using GeoDict show an excellent match:

- The graph above shows the particle size in µm and its fractional efficiency.
- Measurements on the filter sample closely match the simulation results
- Precise simulations with GeoDict improve the design processes and reduce expensive prototyping

**Result:** The validated digital model accurately represents the real world material and enables digital optimization

## Optimization of filter medium

Optimization of filter medium focused on improving the fine fiber layer. Most of the pressure loss occurs in the fine fiber layer, which performs the main filtration task. Digital twins of the fine fiber layer are generated using the FiberGeo module by entering the statistical parameters obtained from the digital analysis with the FiberFind module. An extensive parameter study for the digital optimization of the fine fiber layer includes:

- Optimization parameters: Fiber diameter, Solid Volume Fraction, thickness of the filter media
- In total, 540 digital prototypes were modeled and automatically simulated with GeoDict

| Digital prototype | Δ pressure drop | Δ filtration efficiency | Δ Solid Volume Fraction | Δ Media thickness | Rank |
|---|---|---|---|---|---|
| #38 | - 3.4 % | + 4 % | - 3.8 % | - 18 µm | Overall best |
| #02 | - 10 % | + 0.5 % | - 7.6 % | - 18 µm | Best productivity |
| #32 | - 21 % | - 5.5 % | - 7.6 % | - 27 µm | Best pressure drop |

GeoDict modules used:

- **FiberGeo** to design digital prototypes
- **FilterDict** to analyze performance

**Result:** Digital prototype **#38** shows the most improved performance (see table)

## Math2Market - Our Experts

Math2Market offers GeoDict, a specialized software solution for cutting-edge research and development of new materials. Our team's expertise spans across engineers, physicists, mathematicians, filtration experts, and more, ensuring a comprehensive understanding of your project's needs.

Contact our experts for firsthand insights into how GeoDict transforms research and product development processes.

We offer up to 4-week software trial licenses to test and evaluate our solutions.

Moreover, we suggest an evaluation project tailored to your specific needs. Book an appointment with our experts today and shorten your development cycles.

*Dr. Philipp Eichheimer*

*Christopher Kühnle*

**Scan & Book!**
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**Join over 350 customers worldwide who trust and use GeoDict daily in their workflows.**

**Be part of the success story!**

## Math2Market - The Company

We are one of the world's leading simulation software manufacturers for research and development of new materials. We firmly believe that simulation brings cost-efficient and sustainable innovations in material development.

For over 20 years, we have been continuously developing the GeoDict software and enabling our customers to create the materials of the future - now.

From creating digital twins and predicting their properties to simulating and optimizing digital models - GeoDict is now used worldwide by over 350 companies and research institutions.

GeoDict simulations significantly shorten the development cycles for new materials and time-critical analysis of naturally occurring materials while considerably saving costs. Not only in filtration, but many other industries: new energies and storage, oil and gas industry, additive manufacturing, etc.

We deliver innovation through simulation.

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