Penetration of monodisperse, singly-charged nanoparticles through fibrous filters. Part I – Experimental assessment

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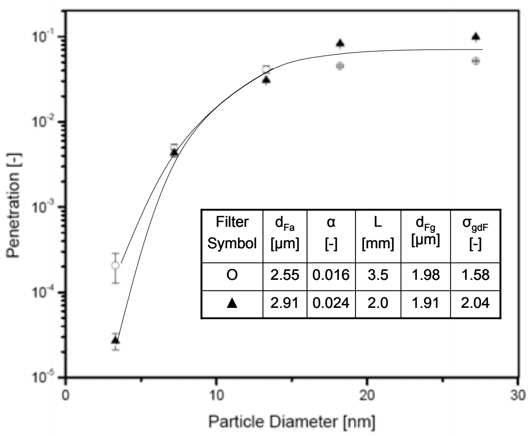
Particle filtration is a very efficient, cost effective and widely applied method of gas cleaning, hence many filtration studies were carried out determining the behaviour of particles in filter media. Most of this research however was made for micrometer sized particles. The extension of filter performance to nanometer sized particles needs still attention and the experimental basis is limited. Some recent studies indicate that the conferment of the classical filtration behaviour based on macroscopic filter and filtration parameters and diffusive deposition is feasible into the nanometer size range (Wang et al. 2007).

We addressed the nanoparticle filtration in fibrous filter media made of melt-blown, polydispersed polypropylene fibers. Challenge aerosols were size classified globular particles (proteins, silica particles) from 3.2 – 27.2 *nm*. They were aerosolized from appropriate suspensions by means of the electrospray (EAG Mod. 3480, TSI, Inc.). The sizing and preparation of challenge particles was done using the PDMA (Parallel Differential Mobility Analyzer). This technique allows a simultaneous measurement of the size distribution of particles in question and in parallel an extraction of a narrow, specific size fraction (Allmaier et al., 2008), which was then used in the penetration study. Particles were carrying one elementary charge; width of the distribution was below about 5%.

The investigated filters were carefully defined by their structural characteristics, such as arithmetic mean fiber diameter, d_{Fa}, filter packing density, α, filter thickness, L, and the geometric mean, d_{Fg}, and the geometric standard deviation, σ_{gdF}, of the fiber diameter distribution. Detailed values are shown in the table within the Fig. 1. In order to minimize the influence of particle diffusion losses on the penetration measurements a test rig containing two identical stainless steel Sartorius™ filter holders connected in parallel was used. One filter holder was furnished with the investigated filter; the other one was used to obtain the upstream concentration at same flow conditions in both branches connected via a 3-way valve to the CPC (Mod. 3025, TSI, Inc.). The flow rate of 1.5 *l/min* resulted in the gas face velocity of 8.96 *cm/s*. Typically 30 alternating upstream and downstream measurements for each particle size were made to obtain good statistics.

Results in Fig. 1 show a decrease in penetration not explainable within the classical filtration theory but with the partially segregated flow model (Podgorski, 2009). We anticipated to see even some increase in penetration due to the thermal rebound and re-entrainment of sub-10nm particles, supposing that here the filtration process particles could be influenced by this phenomenon. Possible theoretical model is given in Part II on the penetration model validation.



Filter Symbol	d_{Fa} [µm]	α [-]	L [mm]	d_{Fg} [µm]	σ_{gdF} [-]
O	2.55	0.016	3.5	1.98	1.58
▲	2.91	0.024	2.0	1.91	2.04

Figure 1. Summary of experimental results.

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