

2011-08

# Porometry, porosimetry, image analysis and void network modelling in the study of the pore-level properties of filters

Gribble, CM

<http://hdl.handle.net/10026.1/2986>

---

10.1016/j.ces.2011.05.013

Chemical Engineering Science

Elsevier BV

---

*All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.*

# Porometry, porosimetry, microscopy, image analysis and void network modelling in the study of the pore-level properties of filters

Christopher M. Gribble <sup>a</sup>, Graham Peter Matthews <sup>a,\*</sup>, Giuliano M. Laudone <sup>a</sup>, Andrew Turner <sup>a</sup>, Cathy J. Ridgway <sup>b</sup>, Joachim Schoelkopf <sup>b</sup> and Patrick A.C. Gane <sup>b,c</sup>

<sup>a</sup> School of Geography, Earth and Environmental Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, UK

<sup>b</sup> Omya Development AG, CH-4665 Oftringen, Switzerland.

<sup>c</sup> Aalto University, School of Science and Technology, Faculty of Chemistry and Materials Sciences, Department of Forest Products Technology, P.O. Box 16300, 00076 Aalto, Finland

\* Corresponding Author: G. Peter Matthews ([pmatthews@plymouth.ac.uk](mailto:pmatthews@plymouth.ac.uk))

## Supplementary Information

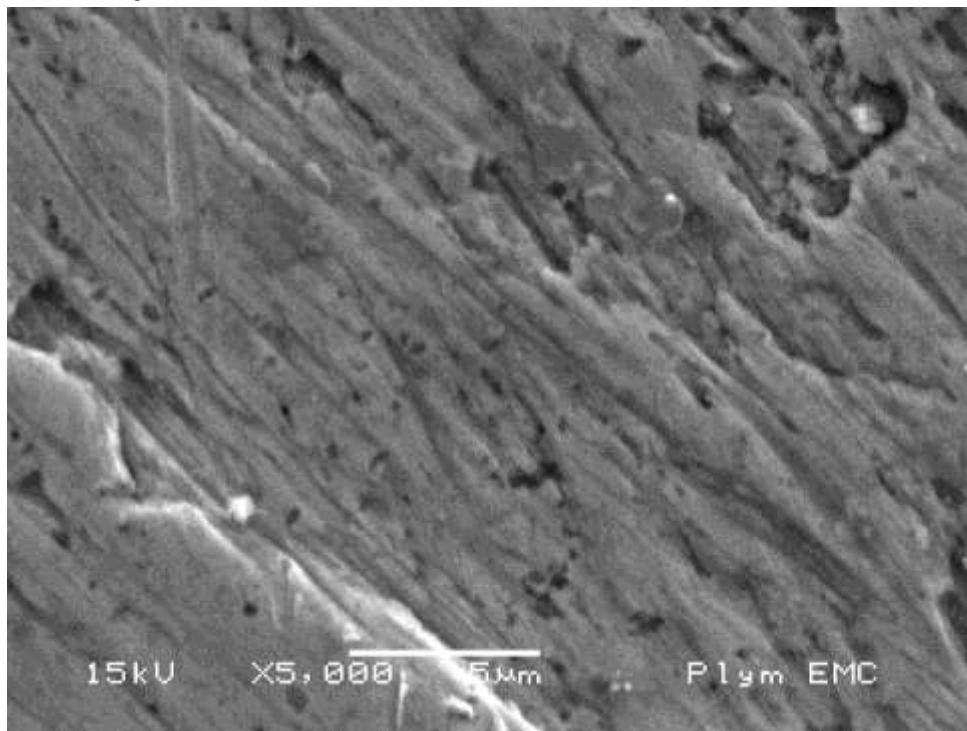


Fig S1. SEM image of Aegis stainless steel sinter, with 5 µm scale bar.

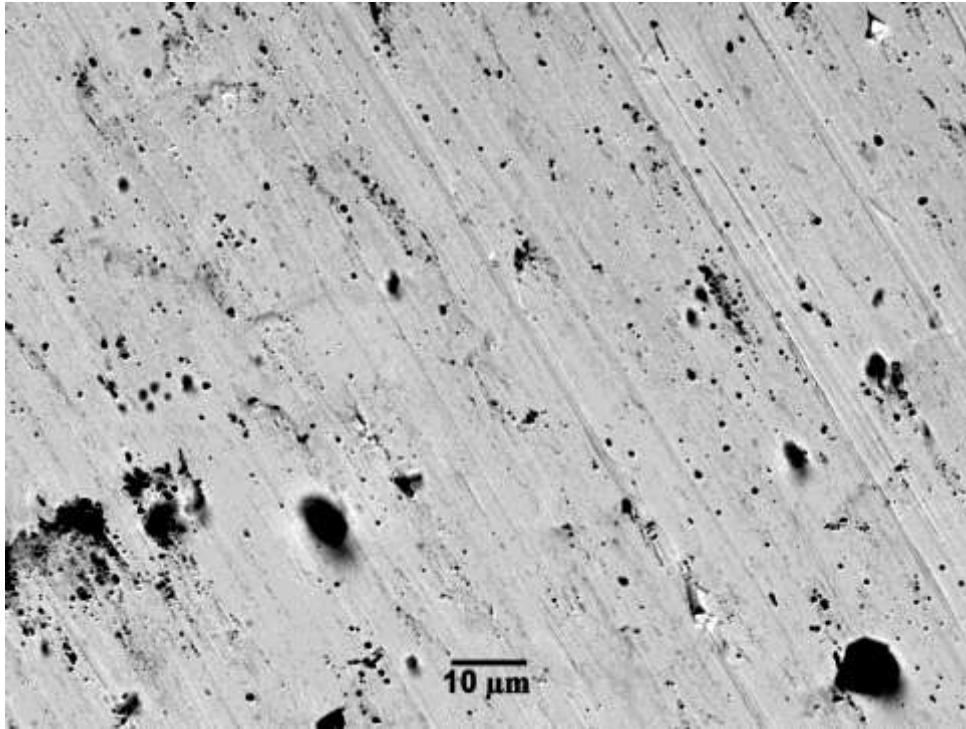


Fig S2. SEM image of fine surface of Porvair stainless steel sinter with 10  $\mu\text{m}$  scale bar.

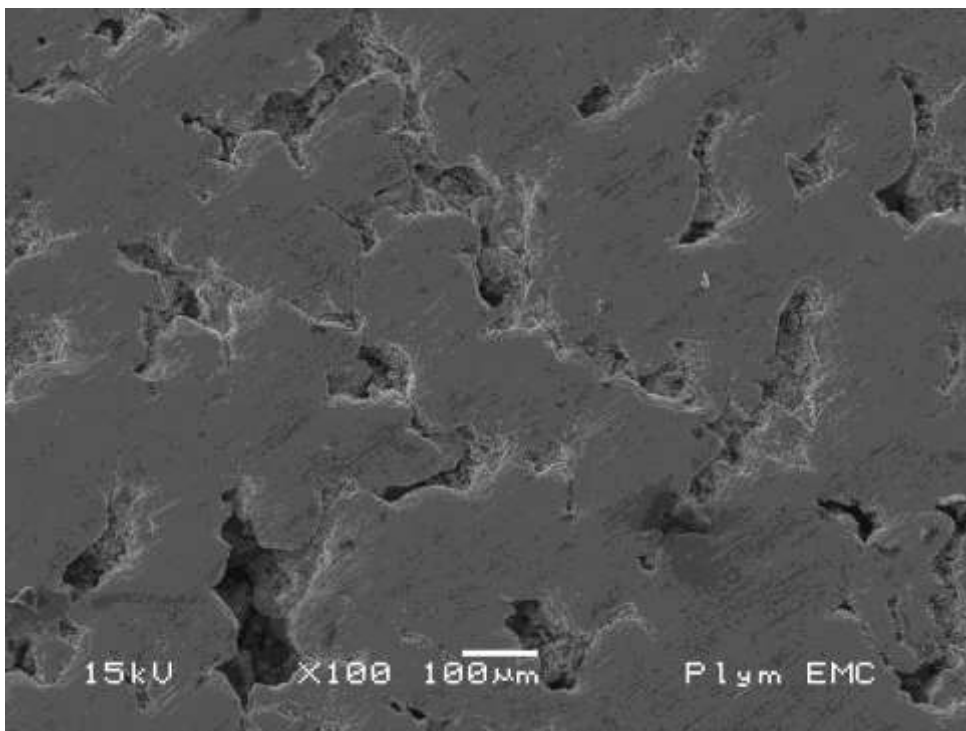


Fig S3. SEM image of coarse surface of Porvair stainless steel sinter with 100  $\mu\text{m}$  scale bar.

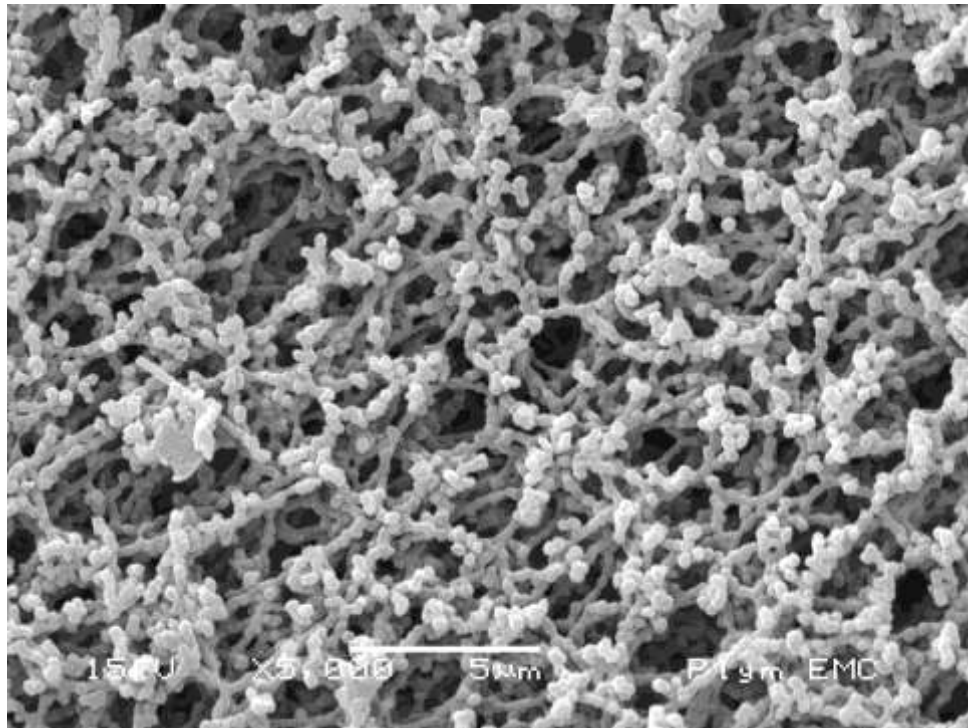


Fig S4. SEM image of cellulose nitrate membrane, with 5  $\mu\text{m}$  scale bar.

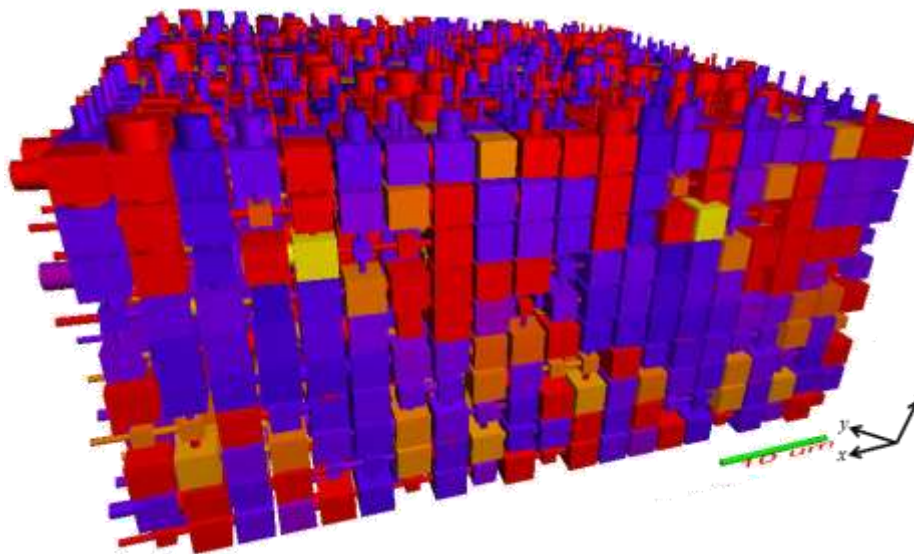


Fig S5. Flow tracking through four identical Pore-Cor unit cells, simulating the structure of the cellulose nitrate filter, at the start of the filtration simulation. Solid phase is transparent. Red: empty, yellow: flow in  $+x$ ,  $+y$  and  $+z$  directions, blue: flow in  $-x$ ,  $-y$  and  $-z$  directions. Less intense colour indicates lower flow. Fluid and particles enter from the top surface and travel initially in the  $-z$  direction.



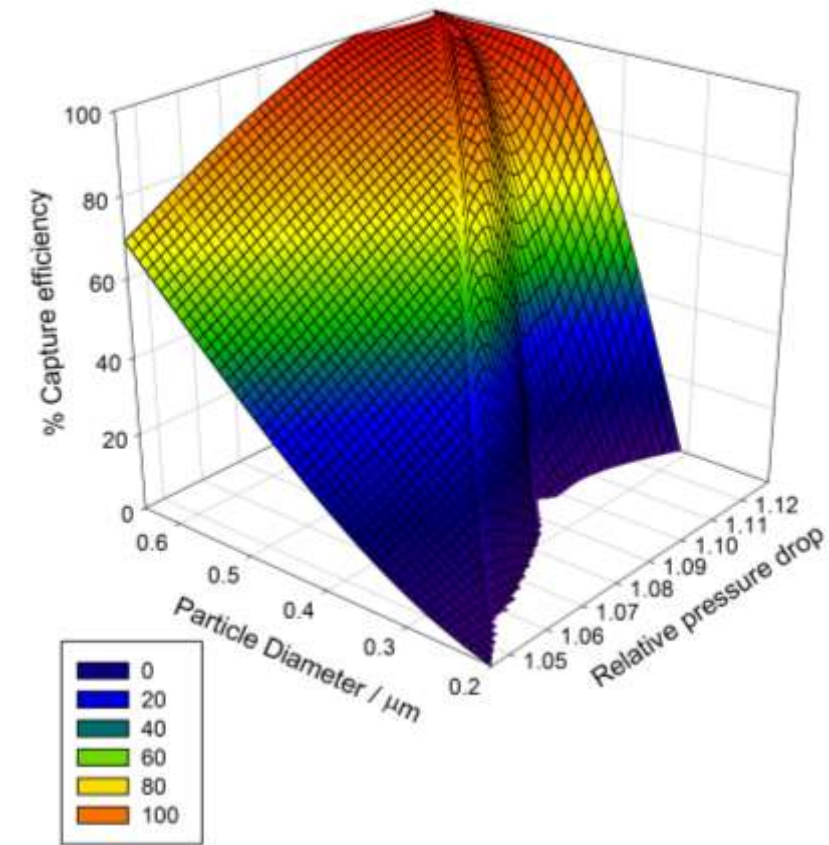


Fig S6. Filtration simulation for cellulose nitrate membrane, filtration rating  $0.45 \mu\text{m}$

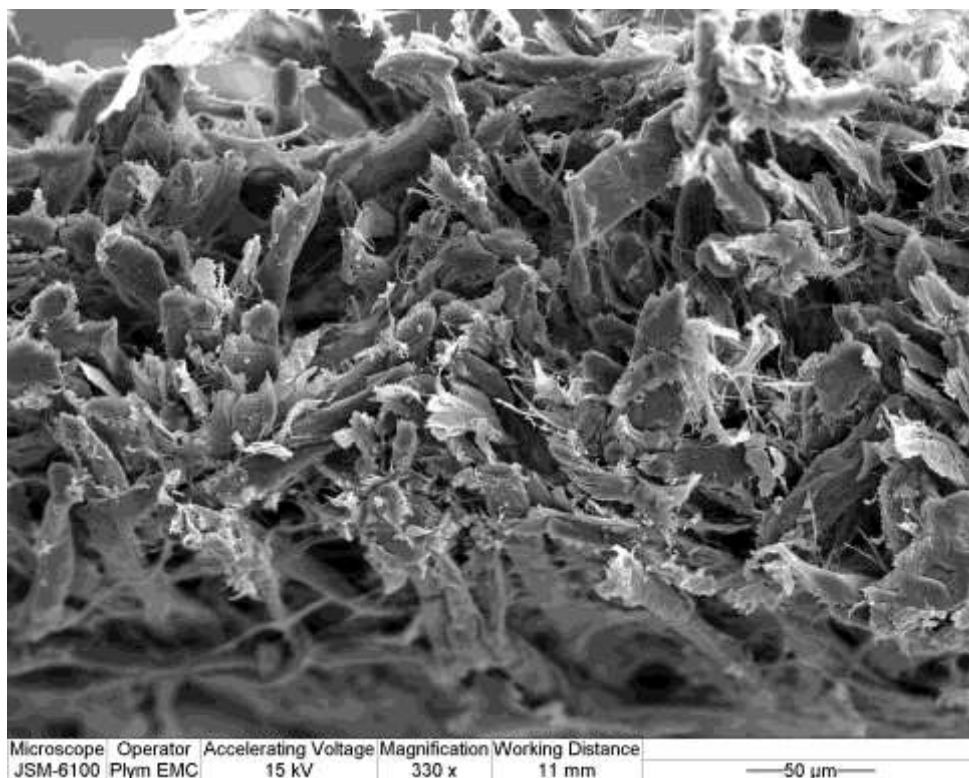


Fig S7. SEM image of grade 1 filter paper, with  $50 \mu\text{m}$  scale bar.

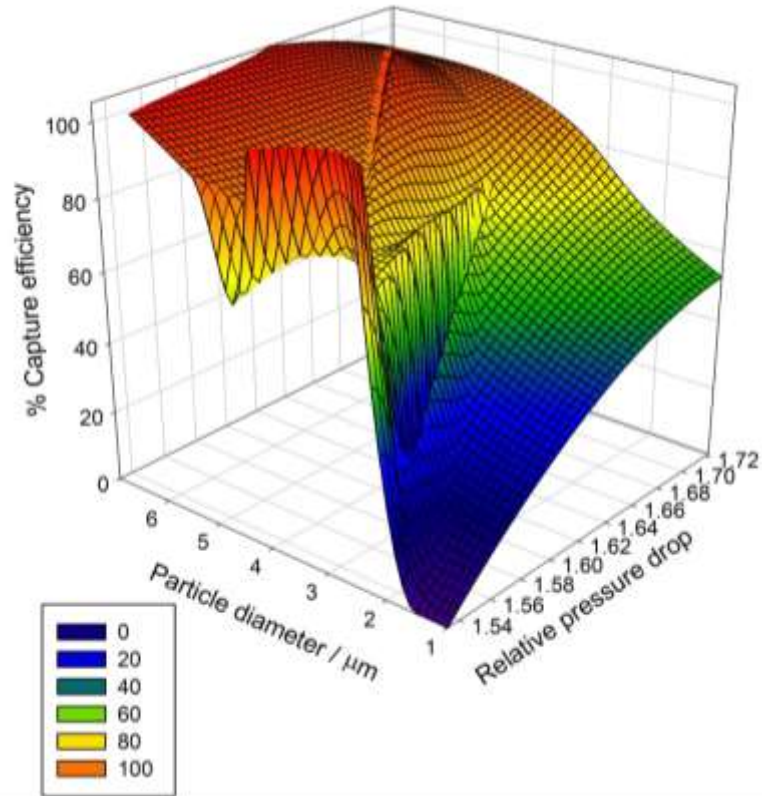


Fig S8. Whatman grade 1 filter paper filtration efficiency graph for 150 particles filtered ranging in size from 1 – 7 microns, filtration rating 4.5 μm.

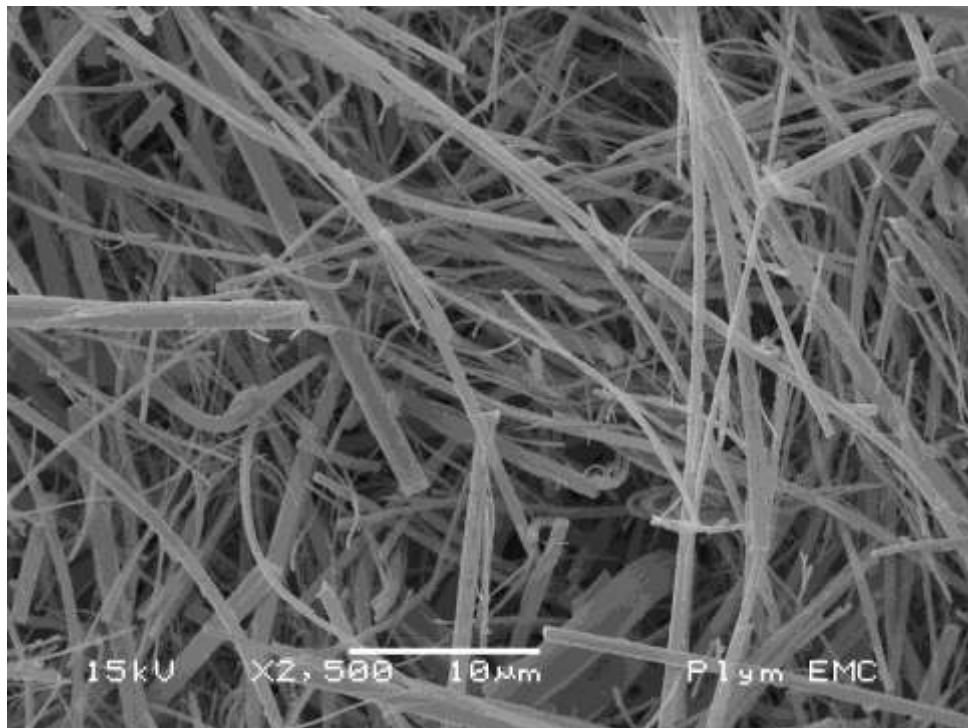


Fig S9. SEM image of glass fibre filter, with 10 μm scale bar.

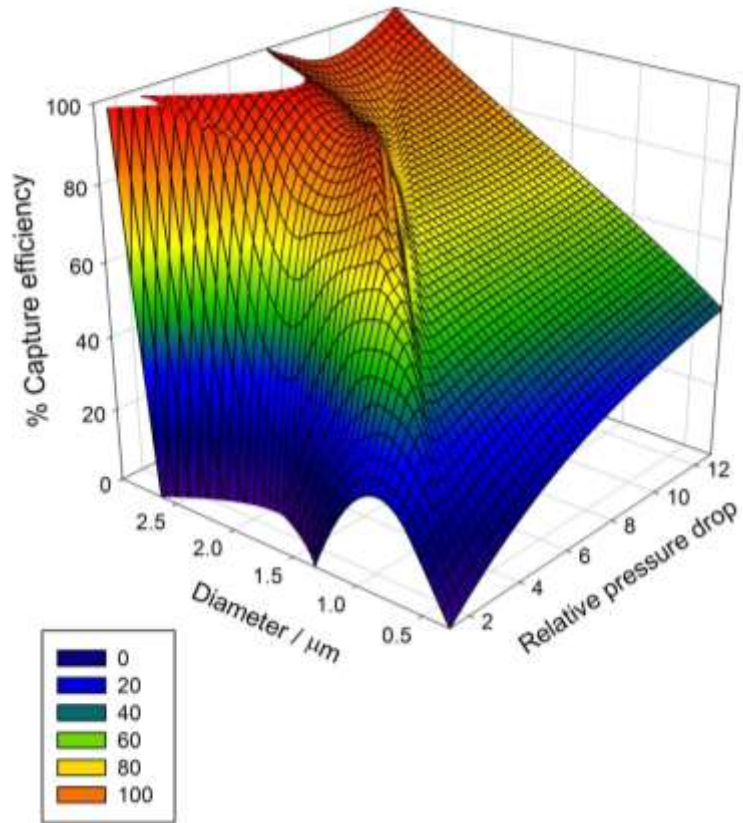


Fig S10. Glass fibre filter filtration efficiency graph for 150 particles filtered ranging in size from 0.25 – 3.00 microns, filtration rating 0.7 μm

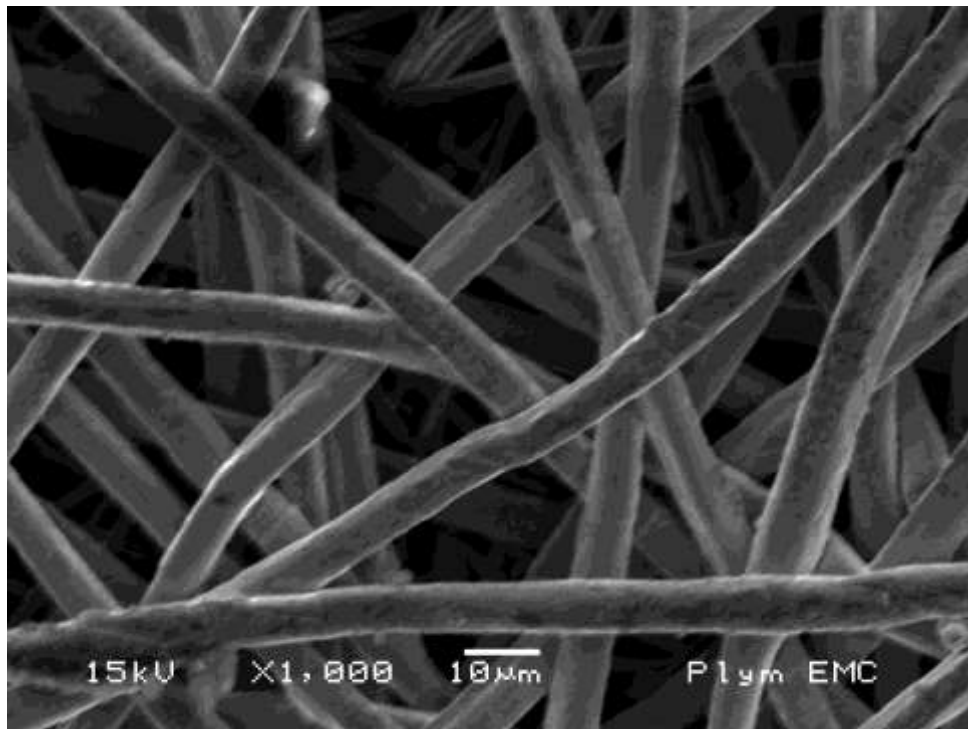


Fig S11. SEM image of surface of stainless steel mesh filter '3AL3' with 10 μm scale bar.



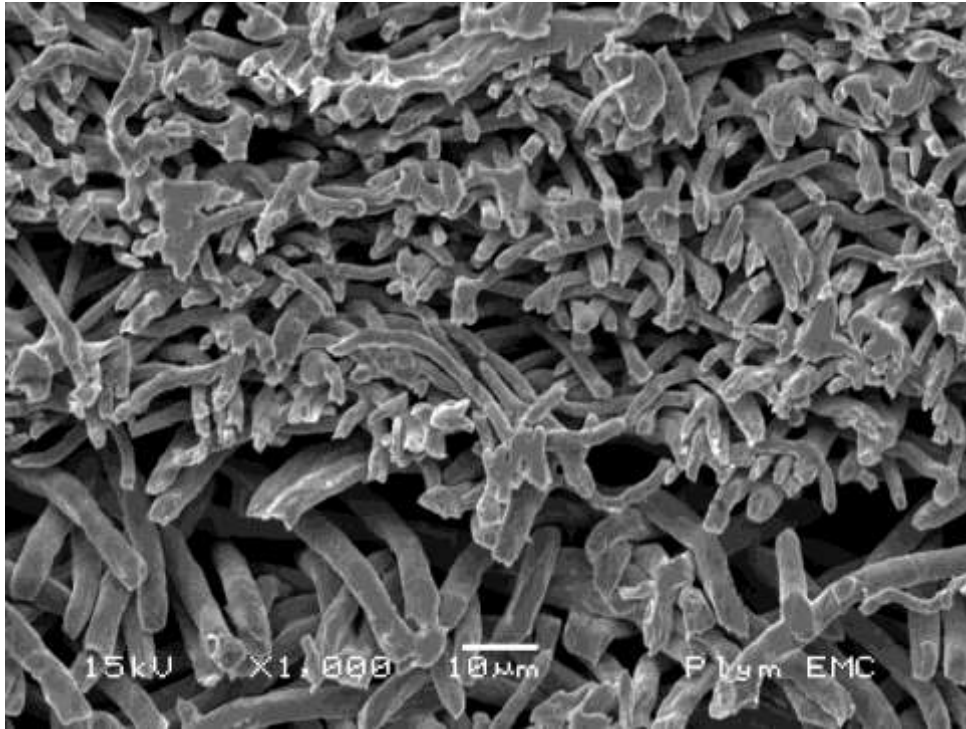


Fig S12. SEM cross-section of stainless steel mesh filter with 10  $\mu\text{m}$  scale bar.

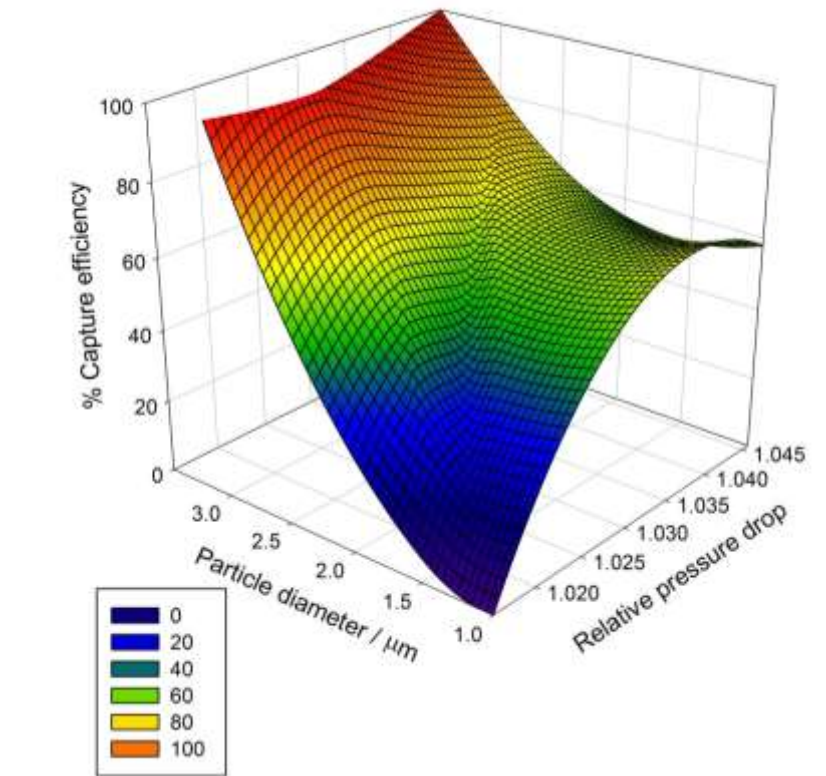


Fig S13. Stainless steel mesh filter filtration efficiency graph for 150 particles filtered ranging in size from 1 – 4 microns, for the fine features of the stainless steel mesh filter, filtration rating 3  $\mu\text{m}$ .



## Network model fitting parameters

The following tables S1 to S7 give the fitting parameters calculated by Pore-Cor Research Suite version 6.31 using its Boltzmann-annealed amoeboid simplex. Five stochastic realisations for fits to each experimental curve were generated, as shown in the left-hand column. Yellow cells are those closest to the average of that parameter for the five stochastic realisations. The most representative structure, i.e. that which has most parameters closest to the average, are highlighted in red. Note that the parameters are coupled by their convergence onto the same experimental data set – e.g. if one parameter is higher, another might be lower to compensate. Therefore it is not valid to use the averages of the parameters, shown in the tables, to generate a representative structure.

Table S1 Stainless steel mesh filter fitting parameters

Porometry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-45.911	0.78387	3.7001	1.0000	0.01
2	-42.353	0.69873	4.0148	1.0132	0.0130
3	-31.785	0.41560	5.6915	1.7724	0.30012
4	-16.688	0.37064	3.8384	5.6708	0.47534
5	-40.756	0.65355	4.2871	1.1692	0.03
Average	-35.499	0.58448	4.3064	2.1251	0.16569
Mercury Porosimetry	Throat Spread	Connectivity	Pore Skew	Correlation Level	Correlation Level
1	6.9810	0.66836	3.7736	2.3819	0.22180
2	-2.9870	0.99969	4.5952	1.0144	0.009
3	0.43388	0.72212	4.1231	1.2824	0.03
4	-0.07	0.81151	4.1130	1.1789	0.10613
5	-1.1408	0.60235	3.9536	5.8988	0.32329
Average	0.64342	0.76081	4.1117	2.3513	0.13804

Table S2 Porvair Stainless steel sinter fitting parameters

Shielded Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	27.311	0.57642	4.7935	17.095	0.18528
2	-0.0008	0.57445	4.4037	1.8747	0.27230
3	-9.7243	0.63392	4.6912	1.2976	0.21786
4	-1.6130	0.48747	4.7848	2.2166	0.37324
5	0.40390	0.51228	5.3356	4.8224	0.37152
Average	3.2754	0.55691	4.8018	5.4613	0.28404
Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	45.152	0.64433	5.7012	9.2131	0.20961
2	48.872	0.65238	5.8220	1.1230	0.15047
3	40.931	0.61980	5.5570	14.195	0.22128
4	47.380	0.61522	5.2929	1.6471	0.0003
5	46.832	0.64041	5.4139	2.1061	0.14233
Average	45.833	0.63443	5.5574	5.6569	0.14480

Table S3 Aegis stainless steel sinter fitting parameters

Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	4.0771	0.69595	5.4332	1.0205	0.53016
2	0.46305	0.41961	5.5496	2.1214	0.91216
3	2.3636	0.66358	5.5009	1.0001	0.50586
4	-1.3429	0.55414	4.9317	1.2075	0.70745
5	40.443	0.75630	5.9261	1.8344	0.11098
Average	9.2008	0.61792	5.4683	1.4368	0.55332

Table S4 Glass fibre filter fitting parameters

Porometry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-45.532	0.59475	4.4817	1.5514	0.04
2	43.180	0.90920	3.1914	1.0764	0.06
3	-20.157	0.44267	3.2763	4.2060	0.47759
4	-32.532	0.55655	3.5709	3.8384	0.48483
5	-38.783	0.50447	5.5445	1.2884	0.009
Average	-18.7648	0.60153	4.0130	2.3921	0.214284
Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	12.024	0.23818	3.3890	284.27	0.82108
2	19.092	0.58841	4.7822	22.366	0.27394
3	33.674	0.84739	4.2427	3.0953	0.02
4	-5.9616	0.69575	4.3567	13.552	0.16328
5	-11.809	0.64309	4.9490	6.6950	0.12490
Average	9.4039	0.60256	4.3439	65.996	0.28064

Table S5 Cellulose nitrate membrane filter fitting parameters

Porometry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-12.474	0.45391	3.3919	1.0018	0.26172
2	-26.397	0.50367	4.2569	1.1983	0.04
3	-12.059	0.27814	5.5228	1.2034	0.39138
4	-23.163	0.52040	3.3727	1.1751	0.02
5	-13.895	0.44763	3.3736	1.0602	0.31896
Average	-17.598	0.44183	3.9836	1.1278	0.20641
Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-19.167	0.43079	3.2772	17.185	0.05
2	-28.252	0.51928	3.4002	33.494	0.16027
3	-24.256	0.42140	4.1057	23.020	0.11187
4	-26.017	0.47790	3.5376	12.182	0.09
5	-25.414	0.49782	3.4764	38.121	0.13226
Average	-24.621	0.46944	3.5594	24.800	0.10888

Table S6 Grade 1 filter paper fitting parameters

Porometry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-28.943	0.54895	3.0580	1.9862	0.38812
2	-31.987	0.79711	3.3674	1.1684	0.24176
3	-44.511	0.58927	5.2530	1.0547	0.02
4	-47.814	0.42088	5.1328	1.1267	0.30652
5	-2.3544	0.92873	3.4256	1.0031	0.02
Average	-31.122	0.65699	4.0474	1.2678	0.19528
Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-11.629	0.72592	3.1029	8.8447	0.34104
2	-28.769	0.84784	3.3019	2.2700	0.33592
3	-13.899	0.85758	3.6288	10.641	0.18073
4	-15.188	0.83954	3.6133	17.667	0.31114
5	-35.215	0.99597	3.8590	10.609	0.16663
Average	-20.940	0.85357	3.5012	10.006	0.26709

Table S7 Track edge membrane fitting parameters

Porometry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-7.0992	0.46657	3.2113	1.0627	0.17162
2	-9.4505	0.26916	5.9142	1.0065	0.007
3	-8.7228	0.26332	5.9550	1.0005	0.006
4	-4.6938	0.41404	2.9205	1.1015	0.15605
5	-5.9038	0.37643	3.1252	1.0007	0.02
Average	-7.1740	0.35790	4.2252	1.0342	0.07213
Mercury Porosimetry	Throat Skew	Throat Spread	Connectivity	Pore Skew	Correlation Level
1	-5.1177	0.50945	2.9723	1.2398	0.25703
2	-33.809	0.61700	4.4360	1.0640	0.13159
3	-7.4634	0.41901	3.3285	1.9638	0.49211
4	2.0620	0.49365	2.9840	3.2816	0.18284
5	-0.9820	0.45120	2.8954	1.0400	0.22156
Average	-9.0620	0.49806	3.3232	1.7178	0.25703