Electret fibers for high efficiency face masks and other filter media - an overview

J. van Turnhout
Dept. Materials Science and Engineering, Faculty 3ME
Delft University of Technology, Mekelweg 2, 2628CD Delft, The Netherlands

Prof. em. J. van Turnhout, Dept. MSE, TU-Delft, The Netherlands. E-mail: j.vanturnhout@tudelft.nl

Abstract:

Most face masks consist of 3 layers, the middle layer of which forms the actual filter, see Fig.1. It consist of melt blown polypropylene fibers of about 2 µm, which are charged by a high tension corona discharge during the production. The fibers are thus turned into electrets. This charging enhances the capturing of submicron particles (like the droplets that carry the Covid-19 virus). This increase in efficiency comes for free, because it does not cause in increase in pressure drop. The long-term storage of charges in polymers is an interesting process that is ruled by surface and interfacial phenomena.

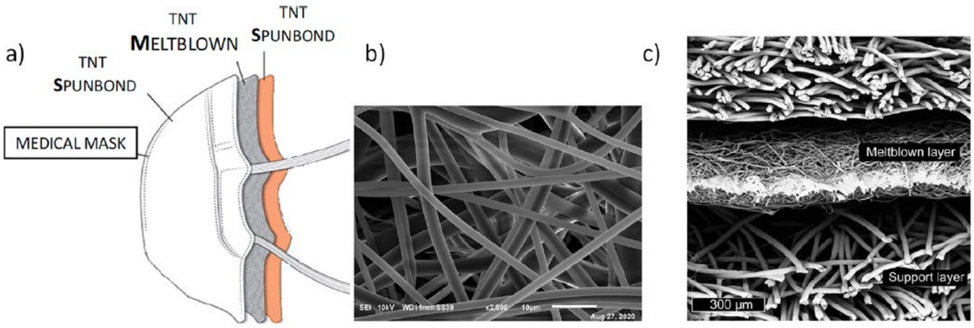

Fig. 1 Face mask made from nonwovens from TNT (Italy). The main filtering is done by the middle MB-layer, with its thinner fibers charged by corona [8].

We will review the past and future use of electret fibers for respiratory protection and other filtration applications. We will start with electret filters made by fibrillation of stretched PP-films highly charged bipolarly with 2 dc-corona's [1]. Next we will outline a special corona set up designed for the on-line charging of melt blown webs [2]. The clue is that we first enclose the web between two

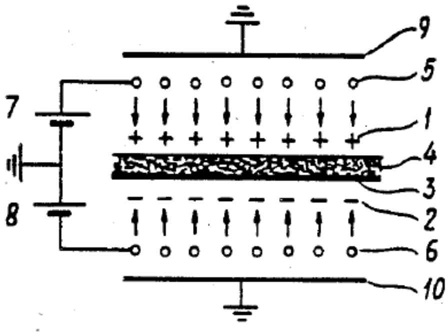

Fig. 2 Two-sided HV corona charging of webs using 2 foils to cover the web [2]. Dielectric barrier discharges are thus created in the many air voids within the web. This secures that bipolar charges are injected into the fibers.

polymer foils of 2 μm, before we charge it from both sides with opposite dc-corona's, see Fig. 2. This again ensures bipolar charging of the fibers. It further prevents holes in the web being formed by sparking. The web can furthermore be compressed by the foils, this offers a simple means to increase the charge density.

Our method differs from the corona charging of webs commonly used [3-12]. This charging is simply carried out by putting the web on a metallic support and corona charging it from one side. This creates a unipolar charge on the fibers, which for several reasons is less attractive. During the talk we will propose a modification of the method advocated in [2] aimed at increasing the bipolar charge density in open porous media.

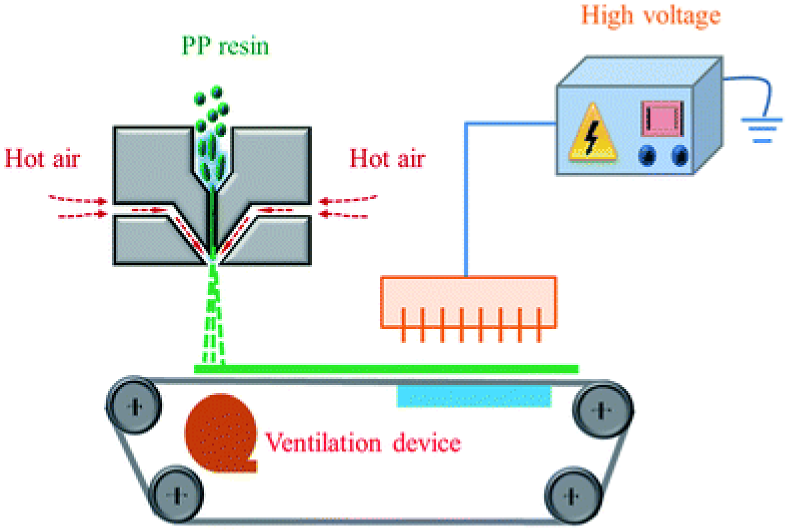

Fig. 3 Common corona charging of a melt blown web from one side, from H. Zhang et al, J. Appl. Polym. Sci. 2018, art.45948. This injects unipolar charges, which are only durable at low charge levels.

Clearly, the stability of the charges with respect to time, temperature and exposure is crucial[3-5,10-12]. We will outline various ways to improve the lifetime of polymer electrets. The crystallinity e.g. plays a crucial role, because the crystallites effectively block any charge transport.

Filtering with electrospun fibers will also be addressed, because spinning with a high voltage produces nanofibers. These strongly enhance the filtering surface and lower the pore size and thus boost the capturing of dangerous particles. Future face masks will therefore likely consist of layers of nano- and microfibers combined [5-12]. They too can be charged with corona.

Finally, we will briefly discuss the reuse, recharging and self-powering of face masks [6-14].

References:

1. J. van Turnhout, W.J. Hoeneveld, J.W.C. Adamse, M. van Rossen: "Electret filters for high-efficiency and high-flow air cleaning", IEEE Trans. Ind. Appl. IA-17 (1981), 240-248.
2. P.T.A. Klaase, J. van Turnhout: "Method for manufacturing an electret filter medium", USA Patent 4588537, 1986.
3. R. Thakur, D. Das, A. Das: "Electret air filters", Separ. Purif. Rev. 42 (2013) 87-129.
4. A. Kilic, S. Russell, E. Shim, B. Pourdeyhimi: "The charging and stability of electret filters", in *Fibrous filter media* ed. by P. Brown and C.L Cox, Woodhead Publ.(2017), pp 95–121.
5. I. Krucinska: "Textiles for resporitory protection", in *Textiles for protection*, ed. by R.A. Scott, Woodhead Publ., 2005, pp 465-502.
6. M.H. Chua, W. Cheng, S.S. Goh, et al: "Face masks in the new Covid-19 normal-materials, testing and perspectives", AAAS Res. 2020, art.7286735, 40 p.
7. K. O'Dowd, K.M. Nair, P. Forouzandeh, et al: "Face masks and respirators in the fight against the Covid-19 pandemic - a review of current materials, advances and future perspectives", Materials (MDPI) 13 (2020), art. 3363, 27 p
8. A.Tcharkhtchi, N Abbasnezhad, et al: "An overview of filtration efficiency through masks - mechanisms of aerosol penetration", Bioact. Mater. 6 (2021), 106-122.
9. I. Armentano, M. Barbanera, E. Carota, et al: "Polymer materials for respiratory protection-processing, end use and testing methods", ACS Appl. Polym. Mater. 3 (2021), 531-548.
10. L. M. Henning, A. Abdullayev, C. Vakifahmetoglu, et al: "Review on polymeric, inorganic, and composite materials for air filters: from processing to properties", Adv. Energy Sustain. Res. 2 (2021), art. 210005, 30 p.
11. S. Jung, J. Kim: "Advanced design of fiber-based particulate filters-materials, morphology, and construction of fibrous assembly", Polymers (MDPI) 12 (2020) art. 1714, 23p.
12. S. Han, J. Kim, S.H. Ko: Advances in air filtration technologies: structure-based and interaction-based approaches, Mater. Today Adv. 9 (2021), art.100134, 13 p.

13. R. Zhang, Q. Xu, S. Bai, et al: "Enhancing the filtration efficiency and wearing time of disposable surgical masks using TENG technology". *Nano Energy* 79 **(**2021), art. 105434, 8 p.
14. E. Hossain, S. Bhadra, H. Jain, et al: "Recharging and rejuvenation of decontaminated N95 masks", Phys. Fluids 32 (2020), art. 093304, 7 p.

Biography:

Jan van Turnhout got an Ir degree in Applied Physics of the Delft University of Techno-logy and a PhD degree from the University of Leyden.

For many years he headed a Group on the Electrical Properties of Polymers, at TNO (Dutch Org. for Applied Scientific Research). Next he became head of the Dept. of Polymer Physics at TNO. His research on electrets was sponsored by Royal Philips and Verto and 3M. It led to the worldwide production of electret microphones and headphones by Philips. It also led to the worldwide production of high efficiency electret filters (brand name "Filtrete") by Verto (Dutch rope factory), and 3M. He further devised a new method called TSD to study relaxations and charge trapping in dielectrics and also developed conducting polymers and piezo-, pyro- and nonlinear optical active polymers.

Between 1989 to 2007 he was professor in Polymer Physics at the TU-Delft, where he set up research on active functional polymers. He further focussed on the analysis of these polymers with dielectric spectroscopy. At present, he is em. professor in the Dept. Materials of Science and Engineering at the TU-Delft.

He wrote two books, 4 chapters, more than 60 articles and over 40 conference papers, and has given many invited lectures. He received the Bernhard Gross award at the International Symposium on Electrets (ISE14). He has edited papers of several conferences on electrets and dielectric phenomena. He co-chaired various International Workshops and Conferences on electrets and related phenomena. He holds several patents on the application of electrets in transducers and electret filters.

Research topics: electrostatics, electrostatic powder spraying, electro/opto/piezo-active polymers, permanent charge storage (electrets), thermally stimulated phenomena, charge distribution diagnostics, dielectric relaxation phenomena, electrode polarization, physical aging, modelling visco-elastic phenomena, Kramers-Kronig conversion, modelling (nano) composites.