

# Corona Charging of Composite Non-Woven Media for Air Filtration

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**Abstract**— The surface potential decay (SPD) measurement is a commonly-used method for monitoring the charge state of non-woven dielectric media for air filtration applications. The aim of this paper is to evaluate the factors that influence the SPD rate of a specific class of filtering media: “M1” consisting in two layers of non-woven polypropylene (PP) attached to a grid of same material and “M2” which has an additional layer of active carbon in between the two PP layers. The samples were charged by exposing them to corona discharges produced by a wire electrode facing a metallic grid parallel to a grounded plate. After charging, SPD was measured in a central point of each sample, for various grid potentials (between  $V_g = 3$  kV and 10 kV) and conditioning temperatures ( $T_e = 21^\circ\text{C}$  and  $75^\circ\text{C}$ ). The experimental results show that the surface potential decreases faster for the material with the carbon layer and is higher for the samples exposed to elevated ambient temperatures or grid potentials.

## I. INTRODUCTION

Standard air filters are composed of fibrous materials, which remove solid particles such as dust, pollen, mold and bacteria [1, 2]. In response to the specific requirements of each application, a wide variety of filter media are presently on the market. They are essentially made of either synthetic (polypropylene, polyethylene, polyester, polystyrene) or natural (cotton, wool) fibers [3, 4].

Non-woven polymeric filter media are widely employed for heat, ventilation and air conditioning [5, 6]. The particle collection efficiency of these filters is known to be enhanced by the static charging of the fibers [7, 8]. Indeed, the fine charged particles that would otherwise go through the air filter might be trapped on the charged fabrics due to the electrostatic forces acting on them. Walsh and Stenhouse [9], as well as F.J. Rornay et al [10] pointed out the effect of using mixed fibers of various layouts on the efficiency collection of electret filters. However, it is important to relate the operating characteristics of the filters to their charging state. A good filter is the one that is capable to preserve as long a time as possible a high level of charge, and hence a high collection efficiency..

Oda and Ochiai [11], Horenstein [12], as well as Kacprzyk and W. Mista [13] have thoroughly studied the corona-charged non-woven filter media, using the surface potential decay measurement techniques previously employed for the characterization of dielectric films, the adjustment of Xerox-photography processes, development of electrets, assessment of cable insulation [14-17]. Recently, the authors made use of the same technique for the study of positive and negative corona-charging of a polypropylene (PP) non-woven media [18-20]. They pointed out that the ionic species generated by the negative polarity corona (C03-, 02-) seem to be more effective for charging this type of media. Thermal pre-conditioning of the materials may enhance the external charge injection, while maintaining a low relative humidity of the ambient air may reduce the superficial moisture and favor the retention of the charge.

In some applications, such as the cabin air filters that are placed in the outside-air intake of the vehicle's passenger, a layer of activated carbon is placed between the non-woven dielectric media [21, 22]. Due to the large surface area of carbon granules, they are excellent at trapping odors and other volatile organic compounds. How does the presence of activated carbon modify the electric charging characteristics of filter media?

The aim of the present paper is to find an answer to the above question, by comparing the SPD measurements performed on two types of PP filters, with and without activated carbon. A special attention is given to the investigation of ambient temperature and relative humidity effects on the capacity of filter media to retain the electric charge and preserve their particle collection efficiency.

## II. MATERIALS AND METHODS

The experiments were performed on 60 mm x 50 mm samples of two non-woven polypropylene (PP) media, designated as "M1" and "M2", in ambient air (temperature: 18°C to 22°C; relative humidity: 25% to 60%). M1 is made of two layers of 2.8 dtex PP fibers (average fiber diameter: 20  $\mu\text{m}$ ; layer thickness: 400  $\mu\text{m}$ ), attached on both sides of a PP grid. "M2" is similar to "M1", but has an additional carbon layer between the grid and one of the PP non-woven fabrics (Fig. 1).

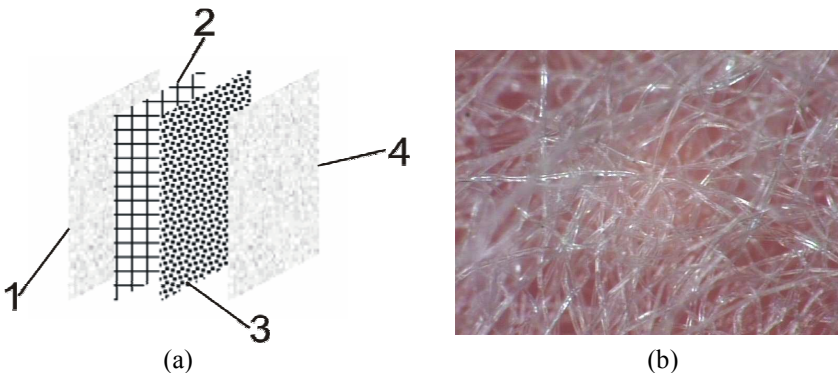


Fig. 1. (a) Composition of the composite media "M2"; (b) Microscopic view of the non-woven PP media. (1 – non – woven layer; 2 – polypropylene grid; 3 – carbon layer; 4 – non – woven layer).



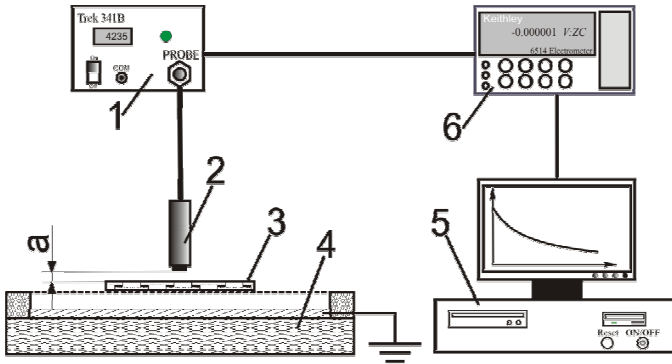


Fig. 3. Experimental set-up for measurement of the surface potential. (1 – electrostatic voltmeter TREK 341B, 2 – voltmeter probe 3450, 3 – non – woven sample, 4 – P. V. C. Support, 5 – computer for data acquisition, 6 – electrometer Keithley,  $a$  – 3 mm).

### III. RESULTS AND DISCUSSION

The average SPD curves recorded for media M1 and M2 after corona-charging using several values of the grid potential  $V_g$  are displayed in Fig. 4. The initial value  $V_{mo}$  of the potential  $V_m$  measured at the surface of the media increased progressively with the grid voltage. In the case of M1,  $V_{mo} \cong V_g$  (Fig. 4,a), and  $V_m$  decays faster for higher values of  $V_g$ . The SPD is steeper in the case of the combined media M2. As the potential  $V_{mo}$  is measured 3 s after corona-charging voltage turn-off, its value is  $V_{mo} \geq V_g$  (Fig. 4,b).

At higher voltages applied to the grid electrode, the so-called “cross-over” phenomena [24, 25] occurred (Fig. 4,b): the higher is initial surface voltage, but the faster is the decay. This is mainly due to the charge injection mechanism, as explained in [26–28]. Thus, at 15 min after corona-charging turn-off, the potential at the surface of the media is  $V_m(10 \text{ min}) = 4.1 \text{ kV}$ , for  $V_g = 10 \text{ kV}$ , which is lower than  $V_m(10 \text{ min}) = 5.3 \text{ kV}$ , for  $V_g = 8 \text{ kV}$ . The presence of activated carbon accelerates all charge relaxation mechanisms, including the charge injection, which explains the “cross-over” phenomena.

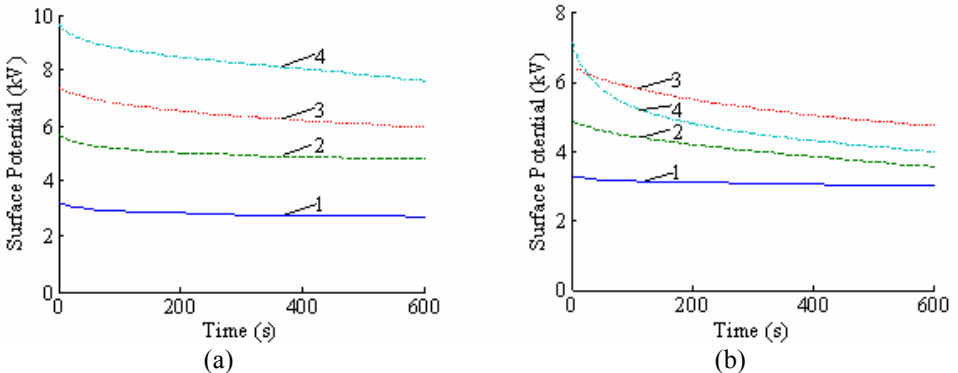


Fig. 4. Surface potential decay curves obtained for (a) „M1” and (b) „M2” samples at: 1– $V_g = 3.5 \text{ kV}$ , 2– $V_g = 6 \text{ kV}$ , 3– $V_g = 8 \text{ kV}$ , 4– $V_g = 10 \text{ kV}$  ( $T_e = 21^\circ\text{C}$  and  $RH = 35\%$ ).

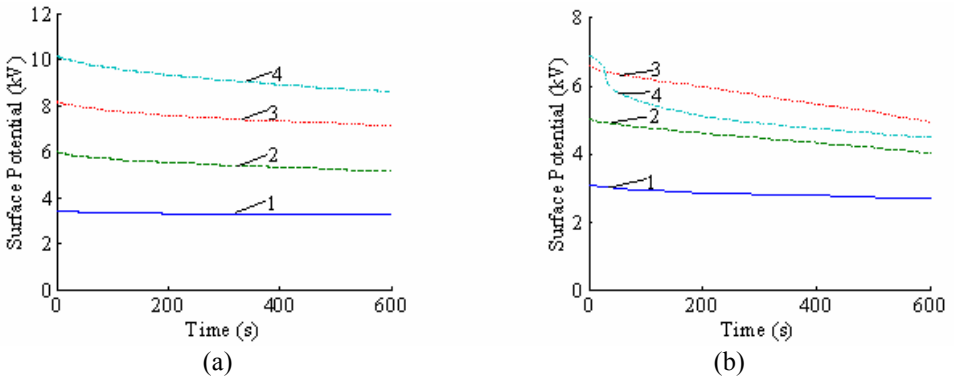


Fig. 5. Surface potential decay curves obtained for (a) „M1” and (b) „M2” samples at: 1- $V_g = 3.5$  kV, 2- $V_g = 6$  kV, 3- $V_g = 8$  kV, 4- $V_g = 10$  kV ( $T_e = 75^\circ\text{C}$  and  $RH = 35\%$ ).

Heating the samples prior to corona-charging may change the aspect of surface potential decay curves (Fig. 5). The decrease of PP fibers surface conductivity with the evaporation of part of the adsorbed water may explain, at least in part, the slow down of surface potential decay in both “M1” and “M2” media. At the same time, with the charges trapped deeper in the samples heated at higher temperature, the potential measured at the surface is more stable in time (Fig. 6).

The higher conductivity of activated carbon, which facilitates the redistribution of the electric charge in the volume of the non-woven media, may explain the faster decay of the potential at the surface of the composite media “M2”, at least during the first 10 min after the corona-charging of the samples (Fig. 7). This process seems to be limited in time, but the volume of data available for longer surface potential decay durations do not allows a firm conclusion on this issue. Further experiments should be conducted, under rigorously controlled environmental conditions, as the relative humidity of ambient air significantly influence the surface potential decay (Fig. 8).

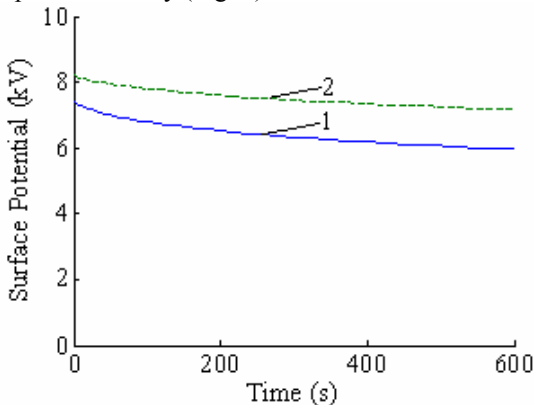


Fig. 6. Comparison between two surface potential decay curves for “M1” samples at  $V_g = 8$  kV, for two temperatures: 1 -  $T_e = 21^\circ\text{C}$  and 2 -  $T_e = 75^\circ\text{C}$  ( $RH = 21\%$ ).

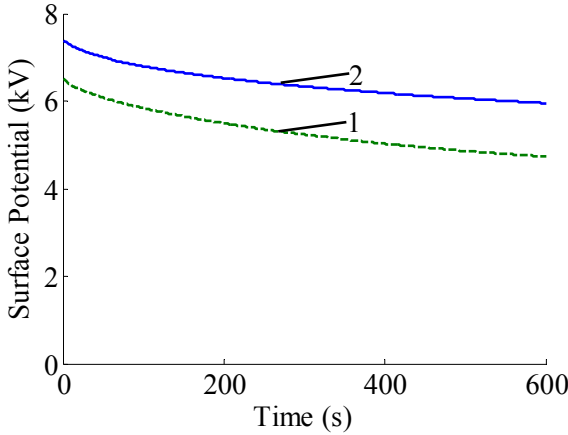


Fig. 7. Surface potential decay curves for: 1 – “M1” ; 2 – “M2”, at  $V_g = 8$  kV ( $T_e = 21^\circ\text{C}$  and  $RH = 21\%$ ).

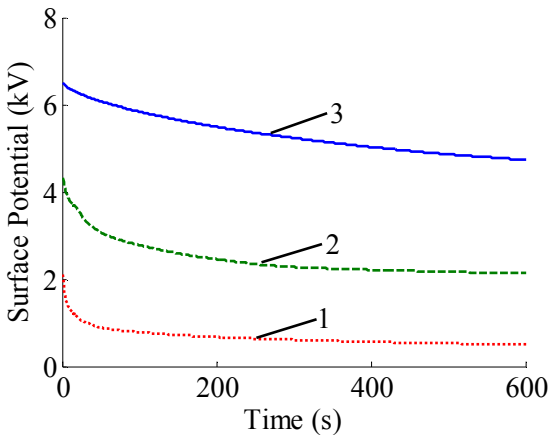


Fig. 8. Comparison between two surface potential decay curves for “M2” samples, at  $V_g = 8$  kV, for three different humidities: 1 –  $RH = 80\%$ , 2 –  $RH = 50\%$ , 3 –  $RH = 21\%$ . The ambient temperature was  $T_a = 21^\circ\text{C}$

#### IV. CONCLUSIONS

- (1) The decay of the electric potential at the surface of combined non-woven media is accelerated when the design of the air filter includes an activated carbon layer.
- (2) Thermal conditioning of the samples and operation at lower  $RH$  of the ambient air may help the media preserve their static electric charges.
- (3) Further researches should be performed in order to dissociate the two mechanisms involved in the surface potential decay, namely the redistribution of the charges in the volume of the media and their neutralization by the ions in ambient air.

## REFERENCES

- [1] T. C. Dickenson, *Filters and Filtration Handbook*, Oxford: Elsevier, 1997.
- [2] D. B. Purchas and K. Sutherland, *Handbook of Filter Media* (second edition), Oxford: Elsevier, 2002.
- [3] C. N. Davis, *Air Filtration*, San Diego: Academic Press, 1973.
- [4] R. C. Brown, *Air Filtration*, Oxford: Elsevier, 1993.
- [5] D.L. Myers and B.D. Arnold, "Electret media for HVAC filtration applications," *INJ Winter*, 2003, pp. 43-54.
- [6] I. M. Hutten, *Handbook of Nonwoven Filter Media*. Oxford: Elsevier, 2007.
- [7] E. R. Frederick, "How Dust Filter Selection Depends on Electrostatics", *Chem. Engr.*, pp. 107 – 114, 1961.
- [8] E. Butterworth, "The Filtration of Dusts. Part. 2: Effect of Electrostatic Charges on Fabrics", *Manufact. Chem.*, pp. 65 – 69, 1964.
- [9] D.C. Walsh and J. I. T. Stenhouse., "Parameters Affecting the Loading Behavior and Degradation of Electrically Active Filter Materials," *Aerosol Sci. Technol.*, Vol. 29, pp. 419-432, 1998.
- [10] Francisco J. Rornay, Benjamzn Y H. Liu, and Soo-Jae Chae., "Experimental Study of Electrostatic Capture Mechanisms in Commercial Electret Filters," *Aerosol Sci. Technol.*, Vol. 28, pp. 224-274, 1998.
- [11] T. Oda and J. Ochiai, "Charging characteristics of a non-woven sheet air filter," *Proceedings 6th International Symposium on Electrets*, 1-3 Sept. 1988, pp. 515 - 519.
- [12] M. Horenstein, "Surface charging limit for a woven fabric on a ground plane," *J. Electrostat.*, vol. 35, pp. 31-40, 1995.
- [13] R. Kacprzyk and W. Mista, "Back Corona in Fabrics", *Fibres and Textiles in Eastern Europe*, Vol. 14, Issue 5, pp. 35 – 38, 2006.
- [14] R.H. Young, "Kinetics of xerographic discharge by surface charge injection," *J. Appl. Phys.*, vol. 72, pp. 2993-2999, 1992.
- [15] P. Molinié, "Charge injection in corona-charged polymeric films: potential decay and current measurements," *J. Electrostat.*, vol. 45, pp.265-273, 1999.
- [16] M. Debska, "Surface potential decay on triglycine sulfate crystal," *J. Electrostat*, vol. 63, pp. 1017-1023, 2005.
- [17] G. Chen, Z. Xu, and L.W. Zhang, "Measurement of the surface potential decay of corona charged polymer films using the pulsed electroacoustic method," *Meas. Sci. Technol.*, vol. 18, pp. 1453-1458, 2007.
- [18] B. Tabti, L. Dascalescu, M. Plopeanu, A. Antoniu, and M. Mekideche, "Factors that influence the corona-charging of fibrous dielectric materials," *J. Electrostat.*, vol. 63, pp. 193-197, 2009.
- [19] B. Tabti, M. Mekideche, M. Plopeanu, L.M. Dumitran, A. Antoniu, P. Molinié, L. Dascalescu, Factors that influence the decay rate of the potential at the surface of non-woven fabrics after negative corona discharge deposition. *ESA/IEEE-IAS/IEJ/SFE Joint Conf. on Electrostat.*, Boston, 2009, Paper P1.05.
- [20] B. Tabti, M. Mekideche, M. Plopeanu, L.M. Dumitran, L. Herous, and L. Dascalescu, "Corona charging and charge decay characteristics of non-woven filter media," *IEEE Trans. Ind; Appl*, Vol. 46, Issue 2, pp. 634-640, 2010.
- [21] H. Marsh, F. Rodriguez-Reinoso, *Activated Carbon*, Oxford: Elsevier, 2006.
- [22] J. W. Hassler, *Active Carbon. The Modern Purifier*, New York: West Virginia Pulp and Paper Company, 1941.
- [23] L. Dascalescu, A. Iuga, R. Morar, V. Neamtu, I Saurasan, A. Samuila and D. Rafiroiu., "Corona and electrostatic electrodes for high-tension separators," *J. Electrostat.*, vol. 29, pp. 211-225, 1993.
- [24] M. Ieda , G. Sawa, and I. Shinhara, "A decay process of surface electric charge across polyethylene film," *Jpn. J. Appl. Phys.*, vol. 6, pp. 793-794, 1967.
- [25] H.J. Wintle, "Surface-charge decay in insulators with non-constant mobility and with deep trapping," *J. Appl. Phys.*, vol. 43, pp. 2927-2930, 1973.
- [26] R. Coelho, "On the significance of charge decay measurements in insulators," *IEEE Proc. 3rd Int. Conf. on Conduction and Breakdown in Solid Dielectrics*, 1989, pp. 212-217
- [27] T.J. Lewis, "Charge transport, charge injection and breakdown in polymeric insulators," *J. Phys. D: Appl. Phys.*, vol. 23, pp. 1469-1478, 1990.
- [28] P. Molinié and P. Llovera, "Surface potential measurements: implementation and interpretation," *Dielectric Materials, Measurements and Applications. IEE Conf. Publ. No. 473*, 2000, pp. 253 –258.