

**STUDIES ON CORONA-CHARGED
POLYPROPYLENE FIBROUS ELECTRETS**

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**DEPARTMENT OF TEXTILE TECHNOLOGY
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STUDIES ON CORONA-CHARGED POLYPROPYLENE FIBROUS ELECTRETS

by

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Submitted

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CERTIFICATE

This is to certify that the thesis titled ‘**Studies on Corona-Charged Polypropylene Fibrous Electrets**’, being submitted by **Mrs. Rashmi Thakur** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by her. She has worked under our guidance and supervision and fulfilled the requirements for submission of the thesis which has attained the standard required for a Ph.D. degree of this Institute.

The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

The corona-charged fibrous electrets are dielectric materials exhibiting quasi-permanent electrical charge imparted by means of corona discharge process. The electrical charge in the electret fibrous materials has been utilized to capture hazardous particles from complex air streams. Air filters of this kind are widely used as respirators and face masks in personal protective equipments, dust collectors in air conditioners, exhaust filters in vacuum cleaners, to name a few. However, the state of our knowledge on the electret fibrous materials is, on the whole, presently still very unsatisfactory. There is no equipment commercially available for preparation of corona-charged fibrous electrets. The role of corona discharge process in determining the magnitude and duration of charge storage in fibrous electrets is not clearly known. The nature of charge decay in the electret fibrous materials is not enough well understood. Further, though it is known that the fibre geometry and material structure play an important role in deciding the filtration efficiency, whether these factors do interact with the corona-charging process factors to enhance the filtration efficiency is not yet known. Also, the relative importance of fibre characteristics, material structure, and corona charging process factors in determining the filtration performance of electret air filters are not fully determined. It is therefore called for a scholarly research aimed at improving our understanding on the development, characterisation and application of corona-charged electret fibrous materials.

In this work, an attempt was made to design and fabricate an integrated corona charging and characterising apparatus. The measurement capability of this apparatus was determined by a gauge R&R study. It was found that the measurement system was deemed capable enough in distinguishing among different grades of fibrous electrets.

Further, an attempt was made to study the role of corona charging process in determining the magnitude and duration of charge storage in fibrous electrets. The response surface design and analysis of experiments coupled with desirability function approach was followed to analyze, predict, and optimise the charge storage capability of fibrous electrets. It was observed that the linear and quadratic effects of point voltage, grid voltage and charging time; the interaction effect of grid voltage with point voltage and charging time were significant in determining the initial surface potential. At the same time, the linear and quadratic effects of grid voltage and charging time, the linear effect of point voltage and the interaction effect of grid voltage and charging time were significant in deciding the half-decay time. Furthermore, the initial surface potential and the half-decay time were optimised simultaneously with an acceptable desirability level.

The charge decay behavior in corona-charged fibrous electrets was explored. The electret charge was found to decay double exponentially. The overall charge decay was supposed to be due to the quick decay of surface charge in addition to the slow decay of bulk charge. The contribution of the slow-decay component was generally found to be greater than that of the quick decay component. The contribution of slow decay component was higher at lower point and grid voltages, lower fibre diameter and higher basis weight. There were optimum charging time and electrode distances at which the contribution of slow-decay component was highest. The rate of charge decay decreased with the decrease in point voltage, grid voltage, fibre diameter, relative humidity and with the increase in basis weight and conditioning temperature. The rate of charge decay was found to be lowest for an optimum charging time, prior and after which the rate of charge decay increased. The decay characteristics were found to be similar for the distance between point and grid electrode till a certain level of distance, after which the

decay rate increased with further increase in distance. A similar observation was made in case of distance between grid and plate electrode.

The spatial charge distribution in polarised polypropylene nonwoven was investigated by employing pulsed electro acoustic method. The polarised nonwoven displayed in-depth charge polarisation with a slow rate of charge decay. The initial charge density in polarised nonwoven was found to increase with an increase in polarisation voltage as well as with an increase in polarisation time. Though the polarisation voltage affected the initial charge density significantly, the polarisation time was not found to be significant. A simple and easy-to-use expression was developed for predicting the initial charge density and it was found to be in satisfactory agreement with the experimental results.

The air filtration behavior of corona-charged fibrous electrets was examined. The electret filter media exhibited higher filtration efficiency than the equivalent mechanical filter media. An attempt was made to explain the air filtration behavior of electret filter media in light of existing theories, however, the theoretical results were found to overestimate the filtration efficiency. The roles of fibre material, media structure and corona charging process in determining the filtration efficiency of electret filter media were studied. The fibre diameter was found to contribute maximum towards the filtration efficiency, followed by grid voltage, basis weight and point voltage, respectively. The filtration efficiency was found to be higher with smaller fibre diameter, higher grid voltage, higher basis weight and higher point voltage. A response surface model was developed to predict the filtration efficiency of the electret filter media and it displayed a very good correspondence with the experimental results. The optimised electret filter media made up of polypropylene meltblown nonwoven fabric with fibre diameter of 1 μm , basis weight of 20 g/m^2 and charged at a point voltage of 12 kV, grid voltage of 3 kV, charging time of

10 min, distance between electrodes of 30 mm was found to filter out particles of 1 μm - 3 μm diameter with a filtration efficiency as high as 86.25 %. The multilayered composite electret filter media consisting of nano- and micro- fibre based meltblown nonwoven fabrics (MmmM structure) displayed the highest quality factor.

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