Probing Charge Degradation in Electret Fibers via Electrostatic Force Microscopy

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1. Introduction

The purpose of this experimental study is to demonstrate the feasibility of using the electrostatic force gradient imaging as an analytical tool to monitor charge in electrically charged fibre, and to probe the solvent-induced charge deterioration of the electret fibre. EFM phase measurements were performed on polypropylene electret fibres prior to and post liquid isopropanol exposure. The behavior of an uncharged glass fiber was also investigated [1].

2. Experimental

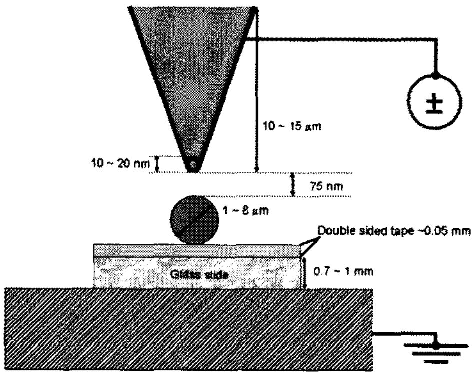

Figure 1. Experimental setup used for electrostatic force measurements on electret fibers

An uncharged mechanical filter media and a corona charged electret filter media were obtained from commercially available filter media commonly used in particulate respirators. The electret filter media used was composed of meltblown polypropylene nonwoven mats charged via corona treatment. ACS grade isopropanol (IPA) was obtained from Sigma-Aldrich (St. Louis, Mo) and used as received. EFM experiments were performed using a Dimension 3000 Atomic Force Microscope equipped with a Nanoscope III controller and an Extender Electronics Module (Veeco Instruments, Santa Barbara, CA). SCM-PIT antimony (n) doped silicon cantilevers coated with a 20 nm layer of Pt/Ir were obtained from Veeco Instruments. EFM experiments.

Three sets of samples were analyzed: M, E and E-IPA. M samples were taken from the uncharged mechanical filter media as received. E samples were taken from the electret filter media as received. E-IPA samples were obtained by immersing E samples into liquid IPA for 2 minutes, removing the excess solvent, and allowing the samples to dry overnight under ambient conditions. Individual fibres were separated from the filter media and laid on a 137DM-2 double sided tape (3M, St. Paul, MN) which was attached to a microscope glass slide (Fisher Scientific, Pittsburgh, PA). The prepared samples were placed on a grounded steel sample holder of the EFM instrument.

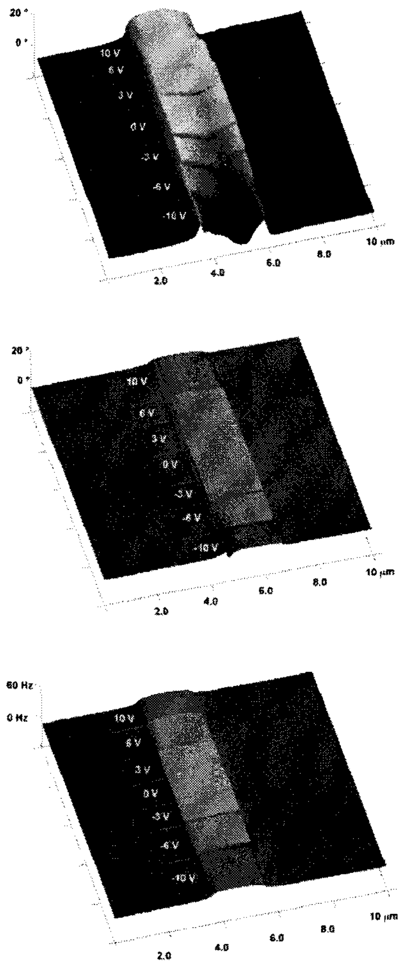

Figure 2. Electrical Gradient Images for electret fibers (E), electret fiber exposed to IPA (E-IPA) and mechanical fibers(M)

A tip-sample separation distance of 75 nm was chosen in order to minimize the effect of the van der Waals forces between the tip and the sample while allowing the monitoring of the long range electrostatic forces. Electrostatic force gradient images were obtained by monitoring the shifts in phase between the oscillations of the biased EFM cantilever and those of the piezoelectric driver as a function of bias voltages applied to the cantilever. A minimum of 10 linescans were obtained for each value of bias voltage applied to the cantilever.

3. Results and discussion

During the EFM measurements, the cantilever was vibrated near its resonance frequency by a small piezoelectric element. The cantilever's resonant frequency changed in response to any additional force gradient that it may encounter as it scans the sample. Attractive forces reduce the cantilever's resonant frequency while repulsive forces increase its resonant frequency. Changes in cantilever resonant frequency due to the presence of a force gradient can be detected by monitoring changes in the phase or the contrast of the force gradient image.

Linescan images of an as-received electret fiber (E) as a function of applied bias voltage (-10 to 10V) at a constant tip-sample separation of 75 nanometers are shown in Fig. 2a. The contrast is generated by the variations in the phase shift angle as a response to the electrostatic interactions between the biased tip and the specimen. When positive bias voltages were used for the tip, the linescans of the electret fiber appeared brighter indicating repulsive interactions between the tip and the sample. When negative bias voltages were applied to the tip, the linescans becomes darker, indicating attractive interactions between the tip and the sample. Figures 2b and 2c illustrate the linescan images for the electret fiber after exposure to IPA and that of a mechanical filter. Both images showflattened contrast indicating low levels of charge[1,2].

4. Conclusions

The degradation of the electrical charge of the fibers used for filtration media were characterized via EFM phase measurements. The ability of monitoring changes in phase shifts as a function of tip bias voltage corroborates the feasibility of using EFM technique as a method to characterize the charges of the individual fibres. The corona charged electret fibre sample (E) exhibited attractive or repulsive response depending on the sign of applied tip bias voltage. In contrast, the uncharged mechanical sample (M) and the isopropanol immersed electret fibre (E-IPA) exhibited only the attractive response for either sign of tip voltages, indicating the dominant effect of the induced polarization effect for the uncharged materials. The observations of dissimilar phase shifts in E and E-IPA indicate that the charges in the electret fibre were indeed reduced after exposure to liquid isopropanol.

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References

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