ELECTRETS TO MEASURE ION CONCENTRATION IN AIR

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Abstract—**Positive and negative ions are produced in air, mainly due to radon and terrestrial/cosmic radiation sources. Measuring ion concentration in air indirectly provides a measure of these sources. Electrets (electrically charged pieces of Teflon), when exposed in the environment, collect ions of opposite sign leading to a measurable decrease in charge, depending upon the exposure time and ion concentration. This work describes a method of correlating electret discharge rate to the ion concentration as measured by a calibrated ion density meter. Once calibrated, electrets can then be used to measure ion concentration of either sign. The ion concentration in ambient air was measured to be about 200 ions mL^{-1}, measured over several hours. Both positive and negative ion concentrations were similar. In a typical room, negative ion concentration was about 3,500 ions mL^{-1}, and, surprisingly, there were no positive ions at all in that room. Being an integrating passive device, the method provides the unique possibility of measuring low or high concentrations of positive or negative ions over extended periods, which is difficult to do with other ion concentration measuring instruments.**
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Key words: electrets; air sampling; detector, radiation; instruments

INTRODUCTION

Radon and terrestrial/cosmic radiation are the main sources of positive and negative ions in air. Measuring ion concentration in air indirectly provides a measure of these sources. Ion generators used for therapeutic applications and devices that generate corona discharges also produce ions in air. Measurement of the concentration of ions is of interest from both the scientific point of view and in industry for assessing the concentration of ions in breathing zones. Even though the concentrations of positive and negative ions are very close to each other in ambient environments, these can be very different from each other in homes and elsewhere because of static fields of either sign on walls, furniture, etc.

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An electret is an electrically charged piece of Teflon of known polarity, and electret ion chamber systems are commercially available and widely used for measuring radon concentration in air and environmental gamma radiation (Kotrappa et al. 1990, 1992). When exposed in the environment, these devices collect ions of opposite sign leading to the measurable discharge of surface potential depending upon the ion density and the exposure time. The rate of discharge of the electret and the ion concentration in air are uniquely related. The discharge of the electrets occurs only by the collection of ions and not from extraneous factors such as changing temperatures and relative humidities. In the present work the electret discharge rate is calibrated against ion concentration in air as measured by a calibrated ion meter. Once calibrated, electrets are then usable for measuring ion concentrations in the ambient environment or in room air.

MATERIALS AND METHODS

Electret ion chamber systems are commercially available under the trade name E-PERM, and are manufactured by Rad Elec Inc. (Rad Elec Inc., 14-C Industry Lane, Frederick, MD 21704). Among other items, such systems include electrets and the electret reader used in the current work. Electrets used in the current work are positive and negative electrets with Teflon thickness of 1.542 mm, referred to as short-term electrets. The surface potential of an electret is measured by using an electret voltage reader. The calibrated ion concentration-measuring device used in the present work is an "Air Ion Counter" manufactured by Alpha Lab (Alpha Lab Inc., 1280 South 300 West, Salt Lake City, UT 84101).

Calibration

Fig. 1 provides the mode of exposure for measuring ion concentration using electrets. The electret is taken out of the storage cap, measured using the electret voltage reader, and positioned on a metallic can. It is ensured that there are no obstructions for at least 1.0 m from the can to minimize deposition losses. The ion collection starts immediately. Positive electrets are used for measuring the discharge rate due to negative ions. An ion meter is

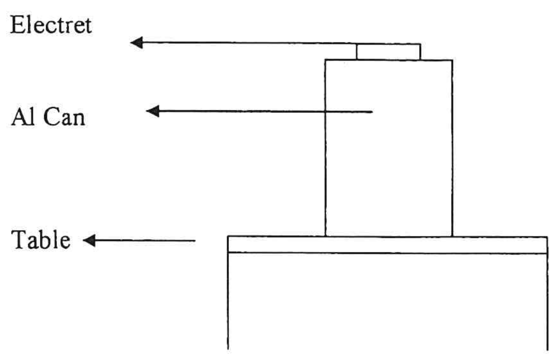

Fig. 1. Schematic for measuring ion concentration using electrets.

used for measuring the negative ion concentration several times during the calibration. For calibration, a location of relatively high ion concentration (3,500 ions mL^{-1}) is used to minimize statistical errors. A positively charged electret is measured (start volts), located on the can for 10 min, removed and measured again (end volts). This step is repeated until the electret reading falls below 100 volts. Table 1 lists the results. The fourth column gives the discharge rate in volts per minute (VPM). The fifth column gives the mid point voltage (MPV), which is simply the average of the start and end voltages. The sixth column is the calibration factor (CF), defined as the electret voltage discharge rate (VPM) per unit ion concentration obtained by dividing VPM by the ion concentration (i.e., 3,500 ions mL^{-1}). As can be seen, the discharge rate is not constant and does depend upon the surface potential of the electret. The higher the potential, the higher the discharge rate, since ions are collected from a larger volume. Eqn (1) gives a statistical fit between CF and MPV:

$$CF = 1784.1 - 242.5 \times \text{Ln}\,(MPV), \qquad (1)$$

where CF is the calibration factor in units of (ions mL^{-1}) per (V min^{-1}), MPV is the mid point voltage, and Ln is the natural logarithm.

Eqn (2) is used for calculating the ion concentration IC (ions mL^{-1}), when the electret discharge rate VPM (V min^{-1}) is known:

$$IC\ (\text{ions } mL^{-1}) = CF \times VPM. \qquad (2)$$

Measurement of ion concentration

A positively charged electret is measured (start volts), located on the can for 10 min (Fig. 1), removed and measured again (end volts). The exposure period (min) is noted. The measurement is repeated at the same location using the same electret. The end voltage of the first measurement becomes the start voltage for the next measurement. Each measurement gives the ion concentration at a 10-min interval.

The discharge rate, VPM, and the mid point voltage, MPV, are calculated. The CF corresponding MPV is calculated using eqn (1). The ion concentration (IC) is calculated by multiplying VPM by CF (eqn 2).

For example, start volts: 500; stop volts: 400; exposure time: 20 min; MPV = 450; VPM = 5; CF = 302.6; ion concentration = CF × VPM = 1,523 ions mL^{-1}.

Experimental measurement of ion concentration

Table 2a lists the results of measurements done in a ground floor office room. Column 4 gives the discharge rate in VPM. Column 5 gives the MPV or the average of the start and end voltages. Column 6 gives the calculated ion concentration. Table 2b lists results from an additional electret placed 1 m away.

Ambient environmental measurements are performed in an open porch with positively and negatively charged electrets in the same measurement arrangement as shown in Fig. 1. A 1-m distance separates the electrets to minimize the influence of one electret upon the other. The results for the positively charged electret are provided in Table 3 and results for the negatively charged electret are provided in Table 4. Measurements indicated that ion concentrations of positive and negative ions are similar.

RESULTS

The calibration carried out is just as accurate as the calibration of the ion meter used in the present study. The

Table 1. Calibration of electret. Exposure in ground floor office, positive ST electret used March 2004. Ion concentration as read by ion meter: 3,500 ions mL^{-1}.[a]

Start volts	End volts	Time (min)	VPM	MPV	CF
745	581	10	16.4	663	213
581	463	10	11.8	522	297
463	352	10	11.1	408	315
352	261	10	9.1	307	385
261	183	10	7.8	222	449
183	119	10	6.4	151	547
119	70	10	4.9	95	714

[a] VPM is the discharge rate in volts per minute; MPV is the mid point voltage; CF is the calibration factor. Fitted equation between CF and Ln (MPV): CF = 1,784.1 − 242.5 × Ln (MPV).

Table 2a. Exposure in ground floor office, positive ST electret used March 2004, 2 pm to 4 pm. Calculated ions mL^{-1} using derived CF.[a]

Start volts	End volts	Time (min)	VPM	MPV	Ions mL^{-1}
745	581	10	16.4	663	4,321
581	463	10	11.8	522	3,146
463	352	10	11.1	408	3,626
352	261	10	9.1	307	3,601
261	183	10	7.8	222	3,697
183	119	10	6.4	151	3,631
119	70	10	4.9	95	3,337
				Average	3,494

Table 2b. Exposure in ground floor office, positive ST electret used March 2004, 2 pm to 4 pm. Calculated ions mL^{-1} using derived CF.[a]

Start volts	End volts	Time (min)	VPM	MPV	Ions mL^{-1}
742	568	10	17.4	655	3,681
568	434	10	13.4	501	3,706
434	316	10	11.8	375	4,092
316	222	10	9.4	269	4,017
222	146	10	7.6	184	3,948
146	89	10	5.7	118	3,581
				Average	3,857

[a] VPM is the discharge rate in volts per minute; MPV is the mid point voltage.

manufacturer of the device reported that the calibration is done using absolute methods and the accuracy is about 10%. This is considered adequate for most measurement requirements. An air pump is used to draw air into the sensitive area. Because of this reason, the ion meter can be on only for short periods. Several short duration measurements are averaged to calculate the correct concentration. Electrets provide the average concentration over the period of measurement.

The slight difference in ion concentrations measured at two locations (Table 2a and Table 2b; 3,494 and 3,857 ions mL^{-1}) can be because of their different locations.

It is of interest to note that the negatively charged electret did not show any discharge at all, indicating the absence of positive ions. This is a surprising observation. This is also confirmed when tested with the ion meter. The reason for this became clear when the surfaces of the room (walls, chairs, and other surfaces) were checked for surface charge using an electret reader. These were found to be highly charged to a negative potential of 500 to 2,000 volts. These surfaces were removing all positive ions from the room air. This may not be so in other situations. The measurements carried out in the ambient environment (Table 3 and Table 4) indicated −220 and

Table 3. Exposure in ambient environment, positive electret used March 2004, 2 pm to 11 pm.[a]

Start volts	End volts	Time (min)	VPM	MPV	Ions mL^{-1}
491	439	60	0.867	465	−255
439	385	70	0.771	412	−249
385	347	60	0.633	366	−223
347	317	70	0.429	332	−161
317	174	308	0.464	246	−208
				Average	−220

[a] VPM is the discharge rate in volts per minute; MPV is the mid point voltage.

Table 4. Exposure in ambient environment, negative electret used March 2004, 2 pm to 11 pm.[a]

Start volts	End volts	Time (min)	VPM	MPV	Ions mL^{-1}
501	447	60	0.900	474	+261
447	388	70	0.843	418	+270
388	343	60	0.750	366	+264
343	301	70	0.600	322	+230
301	170	308	0.425	236	+195
				Average	+244

[a] VPM is the discharge rate in volts per minute; MPV is the mid point voltage.

+224 ions mL^{-1}. It can be concluded that both positive and negative concentrations are similar in the ambient environment. Concentrations did not appear to change significantly over a period of 300 min.

CONCLUSION

1. Electrets provide a simple and easy method of measuring ion concentration of either sign. Electrets are not affected by varying temperatures or humidities. Therefore, it is possible to measure at locations hard to measure by conventional ion meters;
2. Being passive devices with no pump or suction, the ion concentration is not disturbed while measuring the concentration;
3. Being integrating devices, measurements can be extended to longer periods;
4. Using electrets of lower sensitivities, it is possible to measure integrated averages at any desired location over an extended period, such as breathing zones; and
5. The electret ion chamber system is already in use by more than 1,000 users in 25 countries. These users have everything they need to perform this bonus measurement. With one electret voltage reader, several simultaneous measurements can be carried out.

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