Supplemental Information

Flow rate-independent electrical aerosol sensor

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Because the particle charge contributes to both the collection efficiency and the measured current, the fraction of total current measured from the electrostatic particle collector differs from the particle collection efficiency when the charge on the particles is distributed. Considering particles having the same mechanical mobility, the total measured current I_{tot} is the sum of the different charge fractions as shown in equation S1, where n is the number of elementary charges in the particle, c_n is the fraction of particles having n elementary charges, e is the elementary charge, and Q_s is the volumetric sample flow rate. N' is the particle number concentration at the inlet of the electrostatic particle collector. Here $N' = P_{ch}N$, where P_{ch} is the particle penetration through charger and N the number concentration at the inlet of the charger.

$$I_{tot} = \sum_{n=0}^{\infty} c_n N' n e Q_s \tag{S1}$$

The current measured from the collected particles I_{ec} is the sum of the different charge fractions collected according to equation S2. The new terms in the equation are the particle mechanical mobility B and characteristic electrical mobility of the electrostatic collector Z_0.

$$I_{ec} = \sum_{n=0}^{\infty} c_n N' \frac{neB}{Z_0} n e Q_s \tag{S2}$$

Now, for the fraction of the total current measured from the electrostatic collector, $r_{ec} = I_{ec} / I_{tot}$ can be written in the form of equation S3.

$$r_{ec} = \frac{\sum_{n=0}^{\infty} c_n n^2 eB}{\sum_{n=0}^{\infty} c_n n\, Z_0} = n_{qm} \frac{eB}{Z_0} \tag{S3}$$

Equation S3 has the same form as the particle collection efficiency (eq. 3), but the number of elementary charges is substituted by a weighted average charge n_{qm} of equation S4.

$$n_{qm} = \frac{\sum_{n=0}^{\infty} c_n n^2}{\sum_{n=0}^{\infty} c_n n} \tag{S4}$$

Note that taking into account only the charged particles ($n > 0$) would not change the value of n_{qm}.

The current fractions measured from the collected particles were measured in the laboratory characterization measurements. The results obtained for flow rates of 3, 6, and 10 lpm are presented in figure S1. Figure S1a shows the measured current fractions as a function of the particle size for different flow rates. Multiplying the measured fractions with the volumetric sample flow rate, as plotted in figure S1b, normalizes the direct effect of the flow rate. The remaining differences with different flow rates are caused by the decrease in effective particle charge with increasing flow rate. As seen in figure S1a, the collected current fraction is significantly below 1 for most of the measured data points, but reaches 1 at smallest particles for 3 lpm sample flow rate. Therefore, these points are beyond the operational range of the prototype instrument.

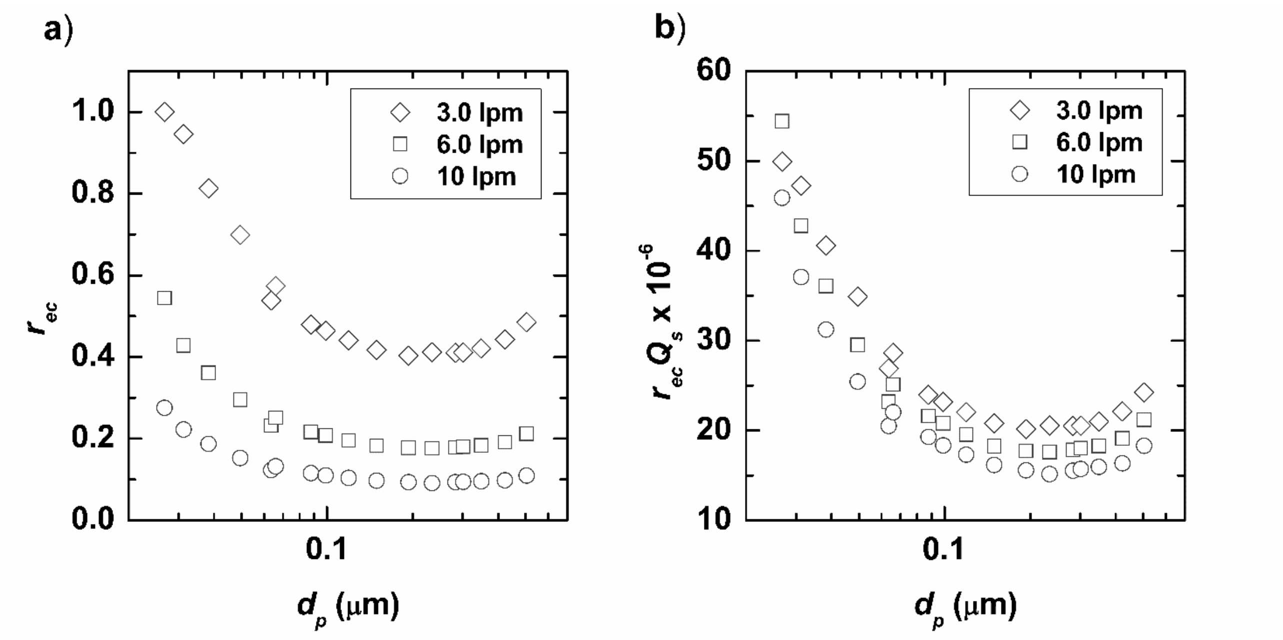

Figure S1. a) The collected current fractions measured from the electrostatic particle collector as a function of the particle size. b) The collected current fractions multiplied by the volumetric sample flow rate as a function of the particle size.

Figure S2 shows the measured overall instrument response function values with a power-law fit for the diameter dependence. The fitted power-law function gives a reasonable fit in the particle size range from 0.025 to 0.250 µm but underestimates the response for larger particles.

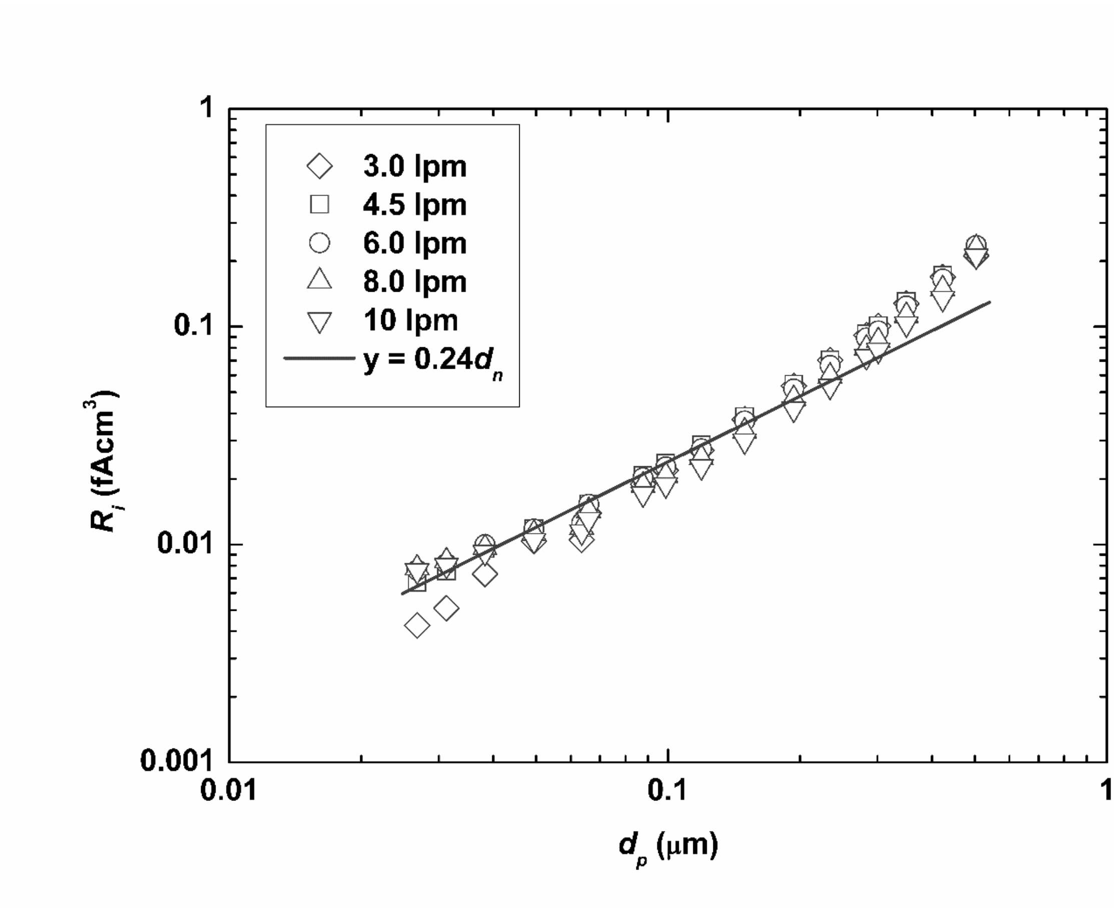

Figure S2. Measured response of the prototype instrument R_i, shown together with a d_p^1 power-law fit for the diameter dependence the response.

The statistical data of the test aerosol size distributions used in the polydisperse test measurements are collected in table S1. The measured size distributions are plotted in figure S3.

Table S1. Statistical data on the lognormal size distribution used in the polydisperse test measurements. Count median size (d_m), geometric standard deviation (GSD), and total number concentration (N_{tot}) shown.

Distribution	d_m (µm)	GSD	N_{tot} (1/cm^3)
1	0.033	1.31	1.59×10^5
2	0.039	1.35	1.04×10^5
3	0.043	1.44	2.45×10^4
4	0.052	1.44	5.60×10^4
5	0.084	1.48	8.43×10^4
6	0.130	1.48	3.56×10^4
7	0.167	1.52	2.96×10^4

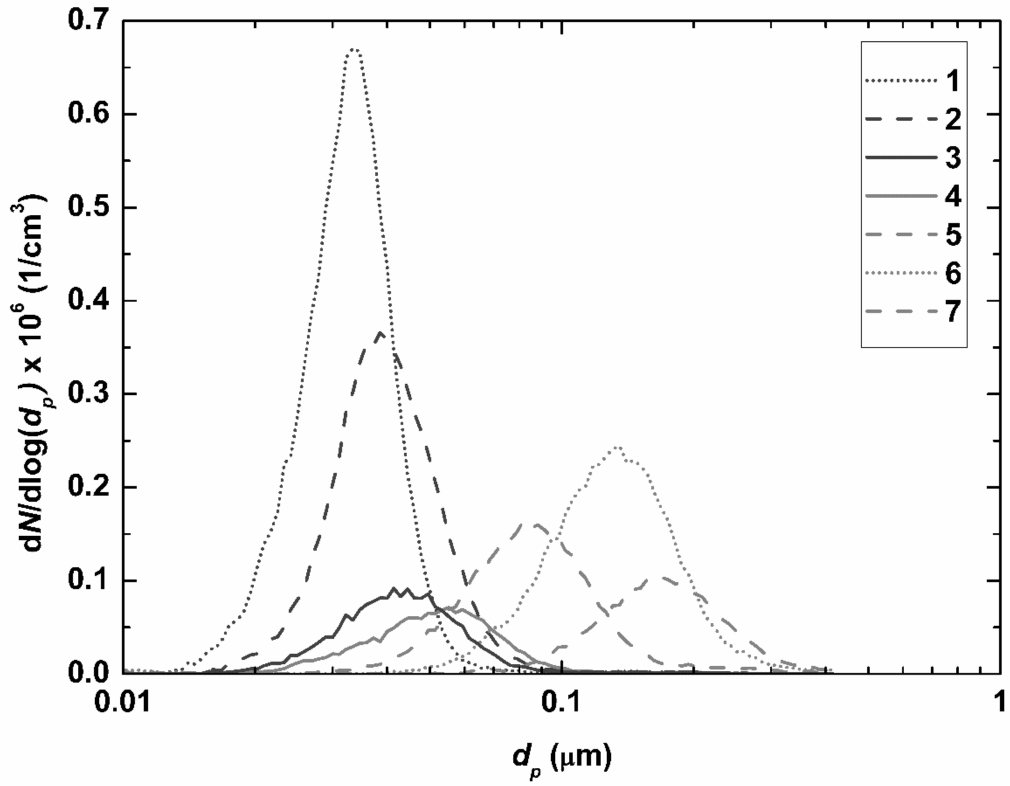

Figure S3. Measured size distributions in the polydisperse test measurements.