Performance of Small Plate and Tube Unipolar Particle Chargers at Low Corona Current

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Appendix A. The effectsof driving voltage and flow rate on the corona current-voltage curves.

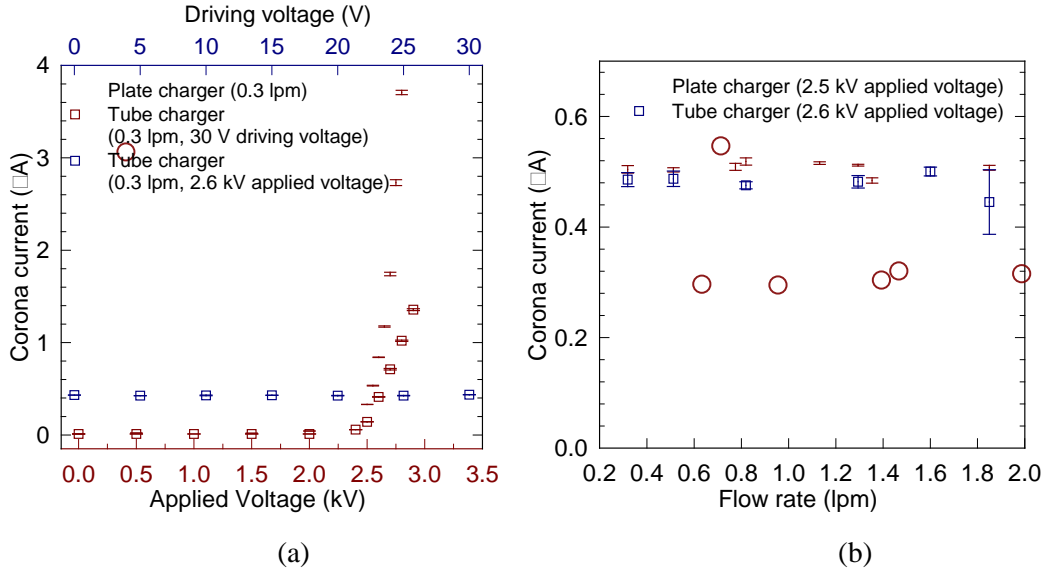(a)   (b)

Figure S1. The effects of driving voltage (a) and flow rate (b) on the corona current-voltage curve.

Appendix B: Estimated particle residence time and ion concnetration in the charging zones of studied chargers.

	Flowrate (lpm)	Plate charger	Tube charger
Residence time (s)	0.3	0.15	0.40
	0.6	0.075	0.20
Ion concentration ($\#/m^3$)	0.3	4.2×10^{13}	2.8×10^{13}
	0.6	5.5×10^{13}	2.7×10^{13}

Note that the listed particle residence time was calculated by the flow rate and volume of charging zone. The ion concnetration was calculated via the fitted Nit values.

Appendix C. Best-fitted equations for particle intrinsic and extrinsic efficiencies of two studied particle chargers

Table S1 Fitted coefficients for intrinsic and extrinsic charging efficienciens η (η=a× (1-exp(-b×d_p)))

Charger type and flowrate	Intrinsic		Extrinsic	
	a	b	a	b
Wire, 0.6 lpm	1.0000	0.0389	0.8404	0.0378
Wire, 0.3 lpm	1.0000	0.0561	0.8880	0.0417
Needle, 0.6 lpm	1.0000	0.0473	0.8389	0.0348
Needle, 0.3 lpm	0.9996	0.0922	0.7693	0.0602

Appendix D. Measured extrinsic charge distributions of particles in the test sizes for two studied chargers
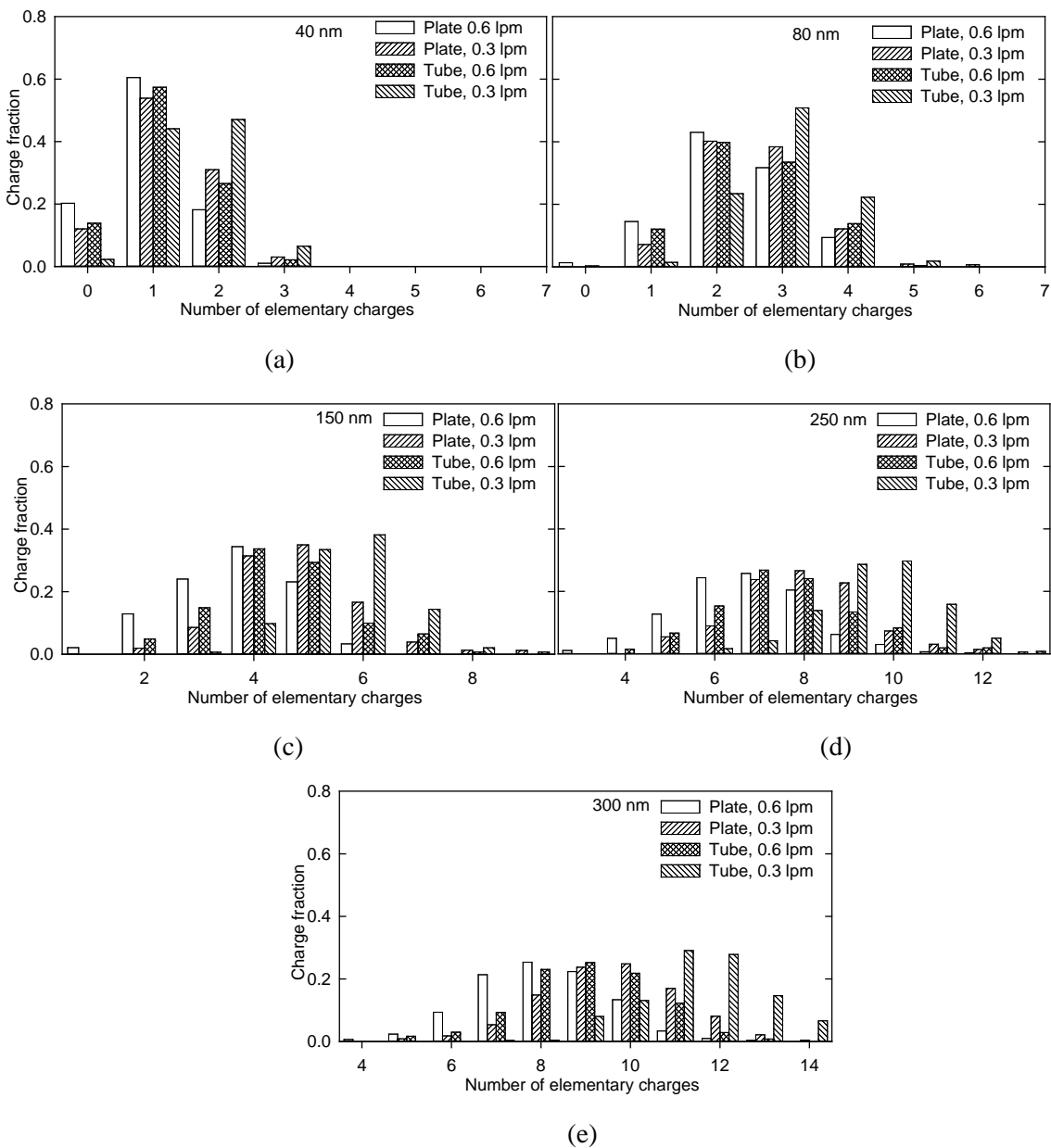

(a)

(b)

(c)

(d)

(e)

Figure S2. Measured extrinsic charge distributions of particles for small plate and tube particle chargers: for the particle size of 40 nm (a); 80 nm (b); 150 nm (c); 250 nm (d); and 300 nm at 0.3 and 0.6 lpm flow rates.

Appendix E. Comparison of measured and calculated extrinsic charge distributions of test particles for two studied particle chargers.

Table S2 Comparison of measured and calculated extrinsic charge distributions of test particles for two studied particle chargers for the plate charger at the flow rate of 0.6 lpm (M: measured C: calculated).

Number of charges		0	1	2	3	4	5	6	7	8	9	10	11	12
20 nm	M	0.49	0.50	0.01	0	0	0	0	0	0	0	0	0	0
	C	0.48	0.51	0.01	0	0	0	0	0	0	0	0	0	0
40 nm	M	0.20	0.61	0.18	0.01	0	0	0	0	0	0	0	0	0
	C	0.14	0.69	0.17	0	0	0	0	0	0	0	0	0	0
60 nm	M	0.09	0.38	0.42	0.11	0	0	0	0	0	0	0	0	0
	C	0.04	0.46	0.45	0.06	0	0	0	0	0	0	0	0	0
80 nm	M	0.01	0.15	0.43	0.32	0.09	0	0	0	0	0	0	0	0
	C	0	0.08	0.39	0.41	0.11	0.01	0	0	0	0	0	0	0
100 nm	M	0	0.14	0.27	0.45	0.14	0	0	0	0	0	0	0	0
	C	0	0.08	0.39	0.41	0.11	0.01	0	0	0	0	0	0	0
150 nm	M	0	0.02	0.13	0.24	0.35	0.23	0.03	0	0	0	0	0	0
	C	0	0	0.06	0.27	0.40	0.22	0.05	0	0	0	0	0	0
200 nm	M	0	0	0.01	0.04	0.20	0.30	0.29	0.13	0.02	0.01	0	0	0
	C	0	0	0	0.04	0.19	0.34	0.28	0.12	0.02	0.01	0	0	0
250 nm	M	0	0	0	0.01	0.05	0.13	0.24	0.26	0.21	0.06	0.03	0.01	0
	C	0	0	0	0.01	0.03	0.13	0.28	0.30	0.18	0.06	0.01	0	0
300 nm	M	0	0	0	0	0.01	0.03	0.10	0.22	0.25	0.22	0.13	0.03	0.01
	C	0	0	0	0	0	0.02	0.09	0.21	0.29	0.23	0.11	0.04	0.01

Table S3 Comparison of measured and calculated extrinsic charge distributions of test particles for two studied particle chargers for the plate charger at the flow rate of 0.3 lpm (M: measured C: calculated).

Number of charges		0	1	2	3	4	5	6	7	8	9	10	11	12	13
20 nm	M	0.35	0.63	0.02	0	0	0	0	0	0	0	0	0	0	0
	C	0.33	0.66	0.02	0	0	0	0	0	0	0	0	0	0	0
40 nm	M	0.12	0.54	0.31	0.03	0	0	0	0	0	0	0	0	0	0
	C	0.05	0.65	0.29	0.01	0	0	0	0	0	0	0	0	0	0
60 nm	M	0.01	0.25	0.47	0.23	0.04	0	0	0	0	0	0	0	0	0
	C	0.01	0.28	0.57	0.14	0	0	0	0	0	0	0	0	0	0
80 nm	M	0	0.07	0.40	0.39	0.12	0.01	0.01	0	0	0	0	0	0	0
	C	0	0.07	0.46	0.40	0.07	0	0	0	0	0	0	0	0	0
100 nm	M	0	0.01	0.23	0.41	0.28	0.07	0	0	0	0	0	0	0	0
	C	0	0.02	0.21	0.48	0.25	0.04	0	0	0	0	0	0	0	0
150 nm	M	0	0	0	0.02	0.09	0.31	0.35	0.17	0.04	0.01	0.01	0	0	0
	C	0	0	0.01	0.09	0.33	0.38	0.16	0.03	0	0	0	0	0	0
200 nm	M	0	0	0	0	0.02	0.02	0.21	0.32	0.26	0.12	0.03	0.02	0	0
	C	0	0	0	0.02	0.04	0.19	0.34	0.28	0.11	0.02	0	0	0	0
250 nm	M	0	0	0	0	0	0.06	0.09	0.24	0.27	0.23	0.07	0.03	0.01	0
	C	0	0	0	0	0	0.02	0.10	0.24	0.32	0.22	0.08	0.02	0	0
300 nm	M	0	0	0	0	0	0.01	0.02	0.05	0.15	0.24	0.25	0.17	0.08	0.03
	C	0	0	0	0	0	0	0.01	0.05	0.15	0.27	0.27	0.17	0.06	0.02

Table S4 Comparison of measured and calculated extrinsic charge distributions of test particles for two studied particle chargers for the tube charger at the flow rate of 0.6 lpm (M: measured C: calculated).

Number of charges		0	1	2	3	4	5	6	7	8	9	10	11	12	13
20 nm	M	0.40	0.58	0.02	0	0	0	0	0	0	0	0	0	0	0
	C	0.39	0.60	0.01	0	0	0	0	0	0	0	0	0	0	0
40 nm	M	0.14	0.57	0.27	0.02	0	0	0	0	0	0	0	0	0	0
	C	0.18	0.73	0.09	0	0	0	0	0	0	0	0	0	0	0
60 nm	M	0.02	0.29	0.48	0.17	0.04	0	0	0	0	0	0	0	0	0
	C	0.01	0.35	0.53	0.10	0.01	0	0	0	0	0	0	0	0	0
80 nm	M	0	0.12	0.40	0.33	0.14	0.01	0	0	0	0	0	0	0	0
	C	0.01	0.12	0.50	0.33	0.04	0	0	0	0	0	0	0	0	0
100 nm	M	0	0.07	0.27	0.39	0.16	0.10	0	0	0	0	0	0	0	0
	C	0	0.03	0.29	0.47	0.19	0.02	0	0	0	0	0	0	0	0
150 nm	M	0	0	0.05	0.15	0.34	0.29	0.10	0.06	0.01	0	0	0	0	0
	C	0	0	0.02	0.16	0.38	0.32	0.10	0.02	0	0	0	0	0	0
200 nm	M	0	0	0.01	0.02	0.12	0.26	0.28	0.21	0.08	0.02	0	0	0	0
	C	0	0	0	0.01	0.09	0.27	0.35	0.21	0.06	0.01	0	0	0	0
250 nm	M	0	0	0	0	0.02	0.07	0.15	0.27	0.24	0.13	0.08	0.02	0.02	0
	C	0	0	0	0	0.01	0.05	0.17	0.30	0.28	0.14	0.04	0.01	0	0
300 nm	M	0	0	0	0	0	0.02	0.03	0.09	0.23	0.25	0.22	0.12	0.03	0.01
	C	0	0	0	0	0	0	0.03	0.10	0.23	0.29	0.21	0.10	0.03	0.01

Table S5 Comparison of measured and calculated extrinsic charge distributions of test particles for two studied particle chargers for the tube charger at the flow rate of 0.3 lpm (M: measured C: calculated).

Number of charges		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
20 nm	M	0.17	0.79	0.04	0	0	0	0	0	0	0	0	0	0	0	0
	C	0.14	0.82	0.04	0	0	0	0	0	0	0	0	0	0	0	0
40 nm	M	0.02	0.44	0.47	0.07	0	0	0	0	0	0	0	0	0	0	0
	C	0.01	0.46	0.50	0.03	0	0	0	0	0	0	0	0	0	0	0
60 nm	M	0	0.18	0.53	0.28	0	0	0	0	0	0	0	0	0	0	0
	C	0	0.08	0.57	0.32	0.03	0	0	0	0	0	0	0	0	0	0
80 nm	M	0	0.01	0.23	0.51	0.22	0.02	0.01	0	0	0	0	0	0	0	0
	C	0	0.01	0.22	0.54	0.21	0.02	0	0	0	0	0	0	0	0	0
100 nm	M	0	0	0.10	0.33	0.44	0.13	0	0	0	0	0	0	0	0	0
	C	0	0	0.04	0.33	0.46	0.15	0.02	0	0	0	0	0	0	0	0
150 nm	M	0	0	0	0.01	0.10	0.33	0.38	0.14	0.02	0.01	0.01	0	0	0	0
	C	0	0	0	0.01	0.09	0.34	0.38	0.15	0.03	0	0	0	0	0	0
200 nm	M	0	0	0	0	0	0.02	0.13	0.32	0.33	0.16	0.04	0	0	0	0
	C	0	0	0	0	0	0.02	0.13	0.32	0.33	0.16	0.04	0	0	0	0
250 nm	M	0	0	0	0	0	0	0.01	0.04	0.14	0.29	0.30	0.16	0.05	0.01	0
	C	0	0	0	0	0	0	0	0.03	0.14	0.29	0.30	0.16	0.05	0.01	0
300 nm	M	0	0	0	0	0	0	0	0	0	0.08	0.13	0.29	0.28	0.15	0.07
	C	0	0	0	0	0	0	0	0	0.01	0.05	0.15	0.27	0.27	0.16	0.05

Appendix F. Fitted Gaussian functions for measured extrinsic particle charge distributions

Small plate charger at the flow rate of 0.3 lpm:

$$f(d_p, q) = [0.3071 + 0.7591 \exp(-1.5285/Kn)] \exp\{-0.5[\frac{q - (2.0693/Kn - 0.0261)}{\ln(1.5874 + 0.6235/Kn)}]^2\}$$

(S1)

Small tube charger at the flow rate of 0.3 lpm:

$$f(d_p, q) = [0.3287 + 0.6754 \exp(-1.2000/Kn)] \exp\{-0.5[\frac{q - (2.4828/Kn - 0.0291)}{\ln(1.5766 + 0.4900/Kn)}]^2\}$$

(S2)