



Supporting Information

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Patterns of Electrostatic Charge and Discharge in Contact Electrification

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SUPPLEMENTAL INFORMATION

Experimental Details:

Preparation of Samples

Glass wafers (Plan Optik) were made of low-alkali glass, had a diameter of 3.0 inches (76.2 mm), and had a thickness of 1.0 mm. The glass wafers were cleaned by first immersing them in a piranha solution (1:4 30% H₂O₂ (aq): H₂SO₄) for 2 hours.

(CAUTION: Under no circumstances should piranha be exposed to organic material!

The peroxide should be added to the sulfuric acid very slowly. Piranha is extremely corrosive, and potentially explosive!) The wafers were then rinsed with ~100 mL of deionized water (Millipore) and ~100 mL 95% ethanol. Glass wafers were dried in a vacuum oven (60 °C, ~50 torr) overnight. Remaining organic contaminants were removed immediately before measuring contact electrification by exposing the plain glass wafers to an air plasma (~500 mTorr) for five minutes. Other procedures for cleaning and drying the samples led to non-linear and irreproducible kinetics of charging

N-Trimethoxysilylpropyl-*N,N,N*-trimethylammonium chloride and 3-(trihydroxysilyl)-1-propane-sulfonic acid (Gelest) were used as received. Silanization of glass wafers was accomplished by immersing plasma-cleaned glass wafers in a 1-mM solution of the silane in ethanol for 30 minutes. The wafers were then rinsed with ~100 mL of ethanol and cured at 70 °C overnight.

Submersing the silanized glass wafers in 1-mM aqueous solutions of NaCl, NaBr, and NaI (for the surface modified with the cationic siloxane) or 1-mM aqueous solutions of LiCl, NaCl, or KCl (for the surface modified with the anionic siloxane) for 30 minutes did not change the polarity of charging.

Ferromagnetic stainless steel spheres (0.125-inch diameter, type 440-C, McMaster Carr) were washed successively with pentane, acetone, water (Millipore), and absolute ethanol. They were dried at 125 °C for at least one hour immediately before use.

Measurement of Contact Electrification

The relative humidity was monitored with a hygrometer (VWR). All measurements were performed at relative humidity = 20–25% and temperature = 22–23 °C. The experiments were performed in a grounded Faraday box (a metal cage) to eliminate the influence of external electric fields on the measurement.

A rotating bar magnet (5.5 cm x 4 cm, inside an IKA Basic variable speed magnetic stir plate) approximately 1 cm below the wafer caused a ferromagnetic stainless steel sphere to roll in a circular path on an insulating surface. As the sphere rolled, the two materials developed opposite charges.¹ The electrode sensed electrostatic charge. Electrostatic charge near or directly above the electrode induced a charge of opposite polarity in the electrode. An electrometer (Keithley 6514) was connected to the electrode (aluminum foil) through the positive terminal of a triaxial cable. The negative terminal of the triaxial cable was grounded. The electrometer was set in charge-measurement mode. The electrometer recorded the charge on the electrode as a function of time: nearby charge induced current in the electrode; this current charged a capacitor of known capacitance (C) in the electrometer. The electrometer measured the voltage (V) across this capacitor, and reported charge (Q) according to the formula $Q=CV$. A LabView program read and stored the charge that the electrode detected as a function of time.

When the sphere was directly over the electrode, the charge that the sphere induced on the electrode ($-Q_s$) was proportional to the charge on the sphere.^{1,2} The

constant of proportionality was determined by comparing the value of Q_s when the sphere was directly over the electrode to the total charge on the sphere, which was measured by dropping it into a Faraday cup.¹ When the sphere was directly over an electrode with a width of 5 mm, the RST measured ~80% of the total charge on the sphere; when the sphere was directly over an electrode with a width of 10 mm, the RST measured ~90% of the total charge on the sphere.³ The values of Q_{max} and Q_{min} reported in Figure 4 are the total charges on the sphere.

(1) J. A. Wiles, B. A. Grzybowski, A. Winkleman, G. M. Whitesides, *Anal. Chem.* **2003**, 75, 4859–4867.

(2) J. Lowell, A. C. Rose-Innes, *Adv. Phys.* **1980**, 29, 947–1023.

(3) R. P. Feynman, R. B. Leighton, M. Sands, *The Feynman Lectures on Physics*, Pearson/Addison-Wesley, San Francisco, **2006**, p. 6-9.

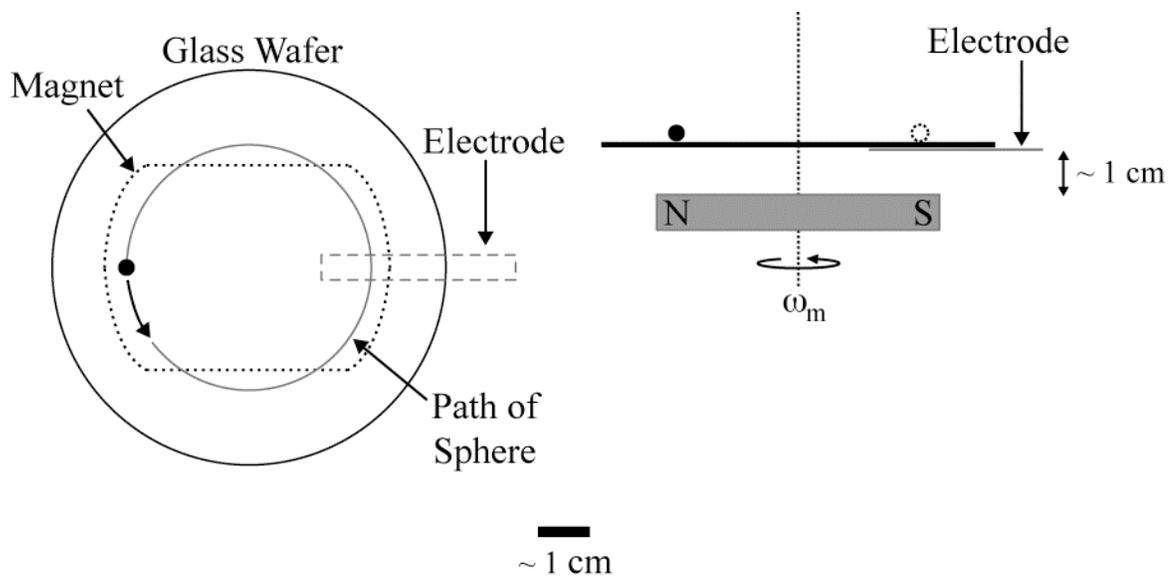


Figure S1. Top-down (*left*) and side-on (*right*) views of the rolling sphere tool.

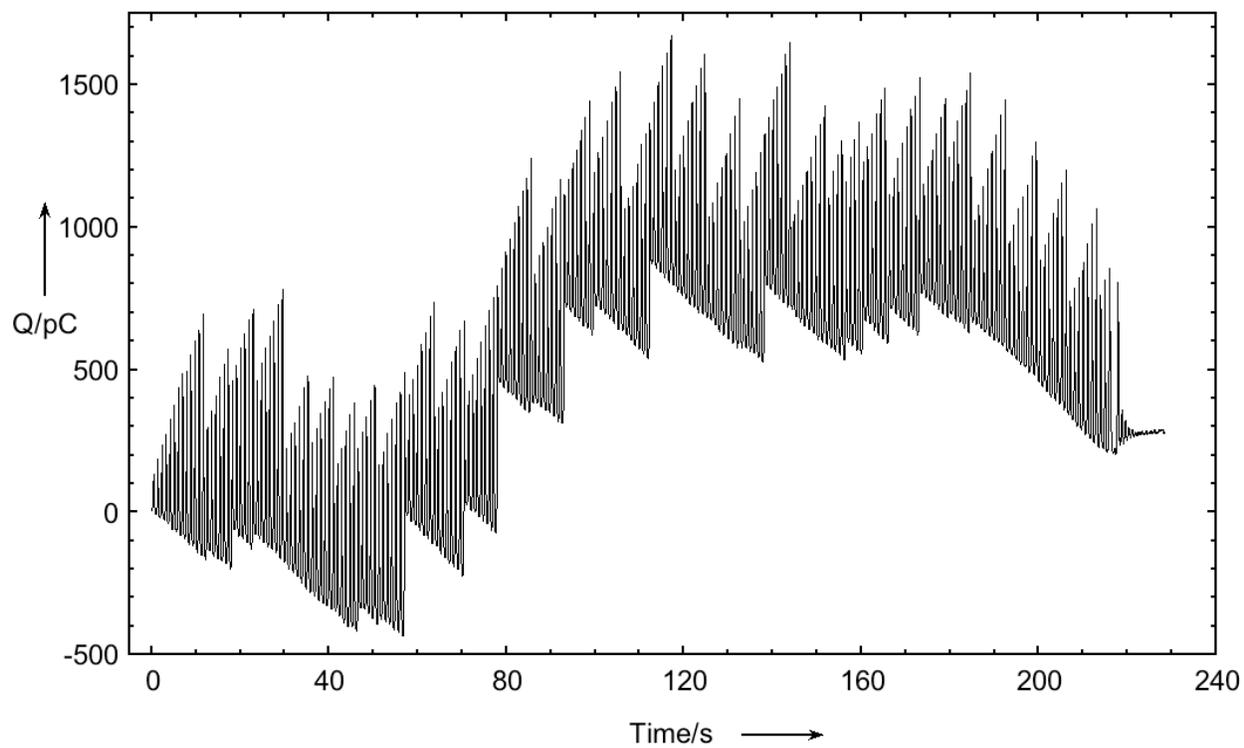


Figure S2. A ~4-minute set of data of a stainless steel sphere ($d = 3.2$ mm) rolling on glass.

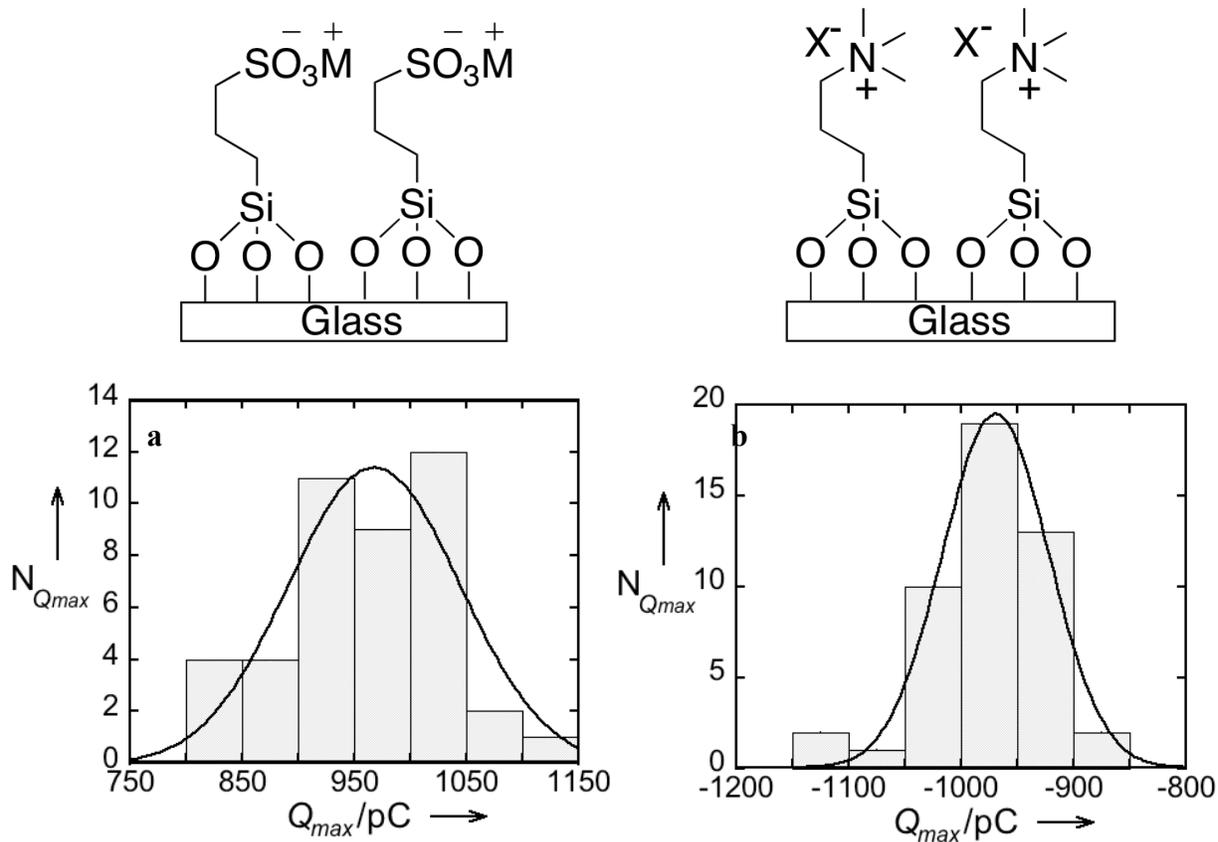


Figure S3: Histogram of measured values of Q_{max} (width of bins = 50 pC) for glass wafers functionalized with ionizable siloxanes. The y-axes, $N_{Q_{max}}$ are the number of times we recorded a value of Q_{max} in each bin. The overlaid curves are the best-fit normal distributions to the experimental distributions of Q_{max} . (a) Glass functionalized with 3-(trihydroxysilyl)-1-propane-sulfonic acid: number of measured values $N = 43$; mean $\mu = 970 \pm 70$ pC; (b) Glass functionalized with *N*-trimethoxysilylpropyl-*N,N,N*-trimethylammonium chloride: number of measured values $N = 49$; mean $\mu = -970 \pm 50$ pC.