Supplemental Information For:

# Controlling the Kinetics of Contact Electrification with Patterned Surfaces

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**Experimental Details:**

Preparation of Samples

Glass slides (VWR) had dimensions of 3.0 inches x 2.0 inches x 1.2 mm. The glass slides were cleaned by washing them by hand with Micro-90 aqueous cleaning solution, rinsing them with water, and immersing them in a piranha solution (1:4 (v/v) 30% $H_2O_2$ (aq): $H_2SO_4$) 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 ~50 mL of deionized water (Millipore) and ~50 mL 95% ethanol. Clean glass slides were silanized by immersing them in a 1-mM solution of the silane **1** (*N*-Trimethoxysilylpropyl-*N*,-*N*,-*N*-trimethylammonium chloride, Gelest) in ethanol for 30 minutes. The wafers were then rinsed with ~50 mL of ethanol and dried in a vacuum oven (60 °C, ~50 torr) overnight.

PDMS stamps were fabricated with standard photolithographic (SU-8 was photoresist) and soft lithographic procedures.[1] The heights of the features of the PDMS stamps were 65 μm. Glass slides were patterned with positively and negatively charging groups using a three-step procedure (Fig S1): i) the entire glass slide was immersed for 30 minutes in a 1-mM solution of **1** in ethanol as described above, ii) a poly(dimethylsiloxane (PDMS) stamp patterned with with protruding cylinders (with diameters 100 μm, 1 mm, or 10 mm) in a hexagonal grid conformally contacted the silanized glass, iii) this assembly was exposed s to an air plasma (5 minutes at 500 mTorr) to produce clean glass in those areas not contacted by the PDMS stamp.

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 under vacuum (~50 torr) at 60 °C before use. Electrically insulating spheres were

**Figure S1**

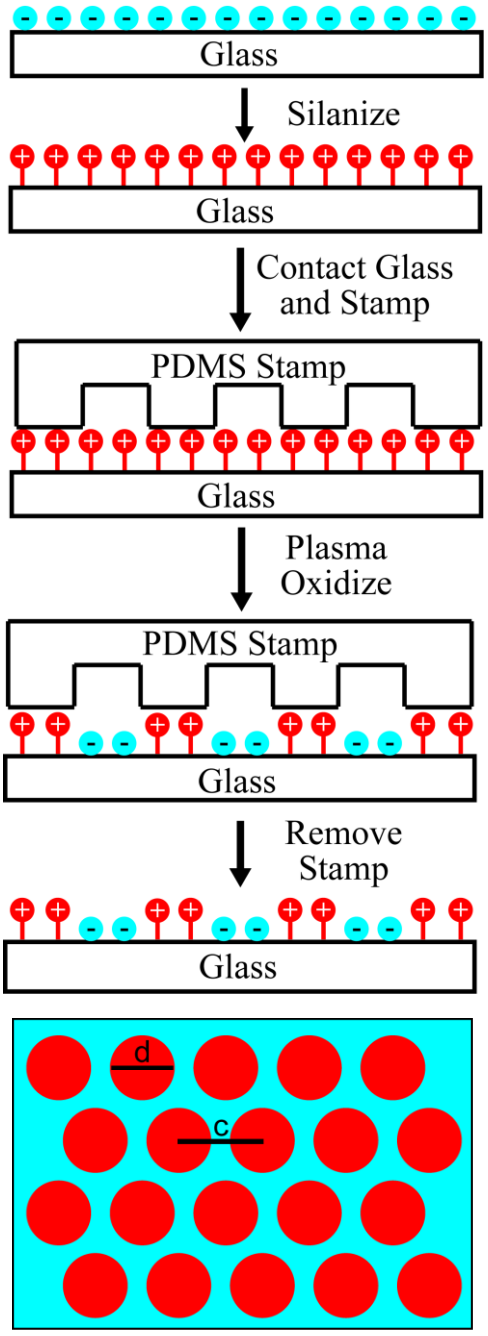



**Figure S1.** Procedure for patterning glass with positively charging (red) and negatively charging (blue) regions. The patterned surfaces (schematically illustrated at the bottom) were circles (on a hexagonal grid) of positively charging, silanized glass surrounded by negatively charging, plasma-oxidized glass. The percentage of surface area covered by the posts is given by the expression $.9069 \bullet d^2 c^{-2}$

stainless steel spheres coated with acrylic waterproofing spray (a copolymer of methyl methacrylate and *n*-butyl methacrylate, Krylon Crystal Clear 1303). About 50 steel spheres were placed in a Petri dish on a magnetic stir plate to keep the spheres in place. A light coating (2-second spray) of the acrylic was applied from a distance of approximately 10 inches. The spheres were covered and allowed to dry under ambient conditions overnight. The dish was then shaken to reposition the spheres over the magnet, and an additional coating was sprayed onto the spheres. This process was repeated ~10 times until the surface resistance of the spheres was not measurable using a handheld digital multimeter.

Measurement of Contact Electrification

The relative humidity was monitored with a hygrometer (VWR). All measurements were performed at relative humidity = 15–20% and temperature = 20–22 °C. The experiments were performed in a grounded, sealed Faraday box (a vacuum oven) to minimize the influence of external electric fields on the measurements.

A rotating bar magnet (5.5 cm x 4 cm, inside an IKA Basic variable speed magnetic stir plate) approximately 1 cm below the glass slide caused a ferromagnetic stainless steel sphere to roll in a circular path on an insulating surface (Figure S2). As the sphere rolled, the two materials developed opposite charges.[i] 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 to 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

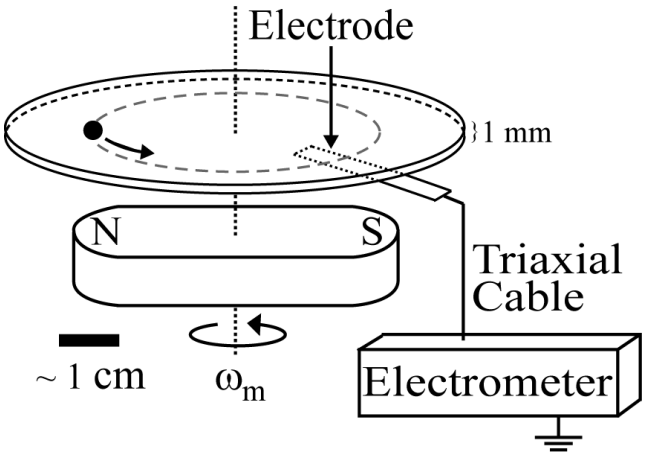



**Figure S2.** Schematic illustration of the "rolling sphere tool" that we used to measure the kinetics of contact electrification between a rolling stainless steel sphere and glass wafers

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.

**Reference**

(1) Xia, Y. N.; Whitesides, G. M. *Annu. Rev. Mater. Sci.* **1998**, *28*, 153- 184.

**Figure S3**

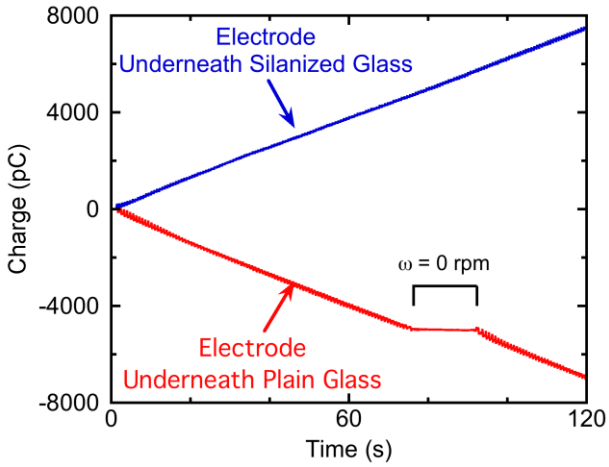
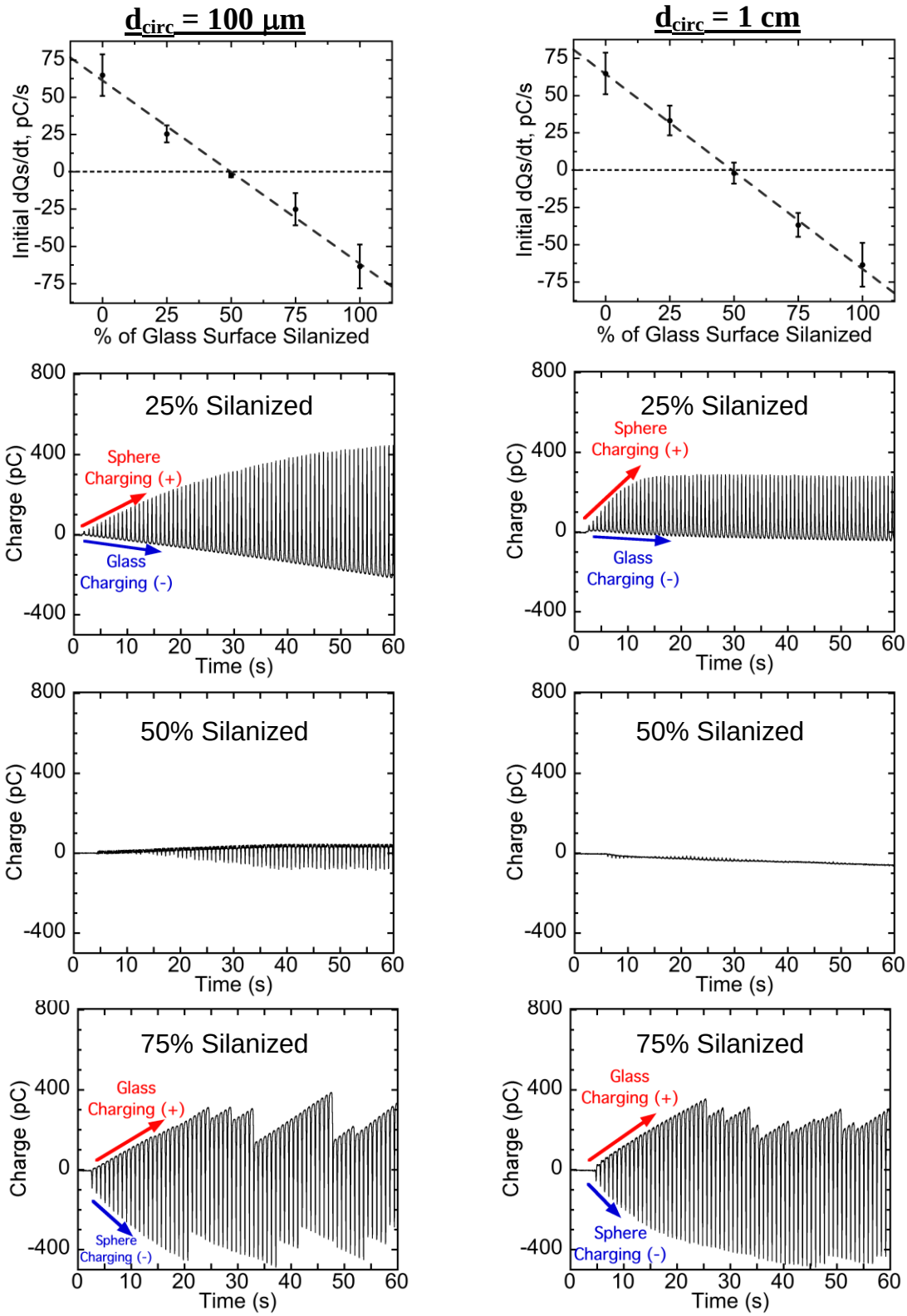



**Figure S3.** Results from two experiments of contact electrification of a steel sphere (*d* = 6.4 mm) rolling on a glass wafer silanized on one half of its area with cationic ammonium-terminated siloxane **1**. The two halves of the wafer charged with opposite signs, while the sphere acquired both positive and negative charge from the two halves of the wafer, and developed only a small (<150 pC, or < 10% of the quantity required for discharge to occur) amount of net charge after 120 seconds. For these experiments, RH = 18–20%. When the bar magnet—and also the steel sphere—stopped moving, charge stopped accumulating on the glass.

**Figure S4 Caption**

**Figure S4.** Rate of charging of a rolling steel sphere ($d$ = 3.2 mm) as a function of the percentage of the glass surface that was silanized with **1** (on 25%, 50%, or 75% of its surface area) in a hexagonal array of circular features with diameter 100 μm or 1 cm. Each data point is the mean of 7–9 measurements; the lengths of the error bars represent the standard deviations of these averages. For these experiments, T = 20–22 °C and RH = 15–20 %.

**Figure S4**


$d_{circ}$ = 100 μm
$d_{circ}$ = 1 cm
Initial dQs/dt, pC/s
% of Glass Surface Silanized
25% Silanized
50% Silanized
75% Silanized
Sphere Charging (+)
Glass Charging (-)
Glass Charging (+)
Sphere Charging (-)
Charge (pC)
Time (s)