Supplementary Material

S-3 i) Experimental setup

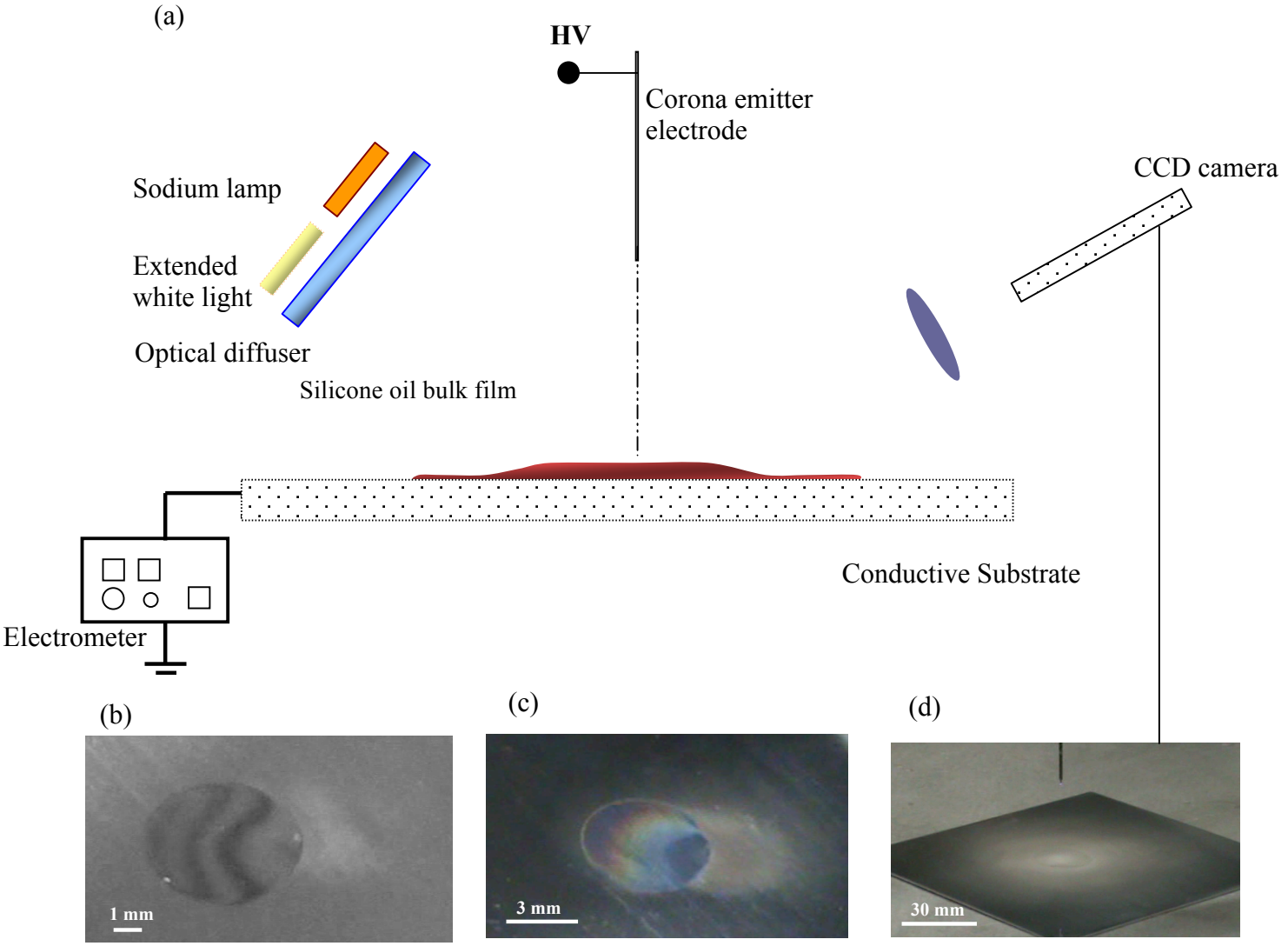

Fig.S3-1 Schematics of experimental setup (a) Silicone oil film spreading over a conductive substrate through corona discharge exposure. (b) Silicone oil film after 2400 *sec* of exposure, (c) after 7200 *sec* and (d) after 1.7×105 *sec* of corona discharge exposure. The corona emitter electrode was hyperbolic needle with a 90 µm radius of curvature and the separation between the corona needle and substrate for all cases was 25 *mm*. The corona voltage and total current was measured to be 17 kV and 40 µA, respectively. Silicone oil viscosity and surface tension were 50 cst and 21 mN/m at 25°C. The electrical conductivity of the oil was measured to be 920 pS/m.

We performed the experiments in an environmental chamber (close chamber with mount and vent). For the experimental runs in the presence of particles, we introduced Arizona dust particles with a given mean diameters (5 μm diameter and 0.5 μm) into a mixing cylinder with a known total weight. The particles mixed with filtered-dehumidified air supply. Then the mixture of particle and pressurized air (4 bar) introduced into the environmental chamber with corona discharge setup. The flow rate was controlled by a needle valve. The environmental chamber was equipped with 0.3 μm filter at the vent section on the top. The flow rate of air/dust mixture was 5 cc/min and kept constant during all experiments. After depositing the precursor film, the mass gain of the substrate was measured with a micro-balance. Since the exact weight of substrate and oil droplet on the top was known the substrate mass gain equals to the particle layer deposited over the oil layer. Measuring the time of experiment we can estimate how much particle is introduced to the substrate with oil per every hour of experiments. We repeat the experiments for dust particles with mean diameter of 0.5 μm. In the case of clean air, we did not introduce any particles into the chamber but feed with pre-filtered clean air. Airflow in all experiments ensures the proper ventilation to avoid severe corona needle corrosion due to the ozone accumulation in the chamber.

S3 ii) Surface potential measurements

For voltage and electric field measurement on the surface of the film, Keithley-6514 electrometer was used. The probes were thin conductive wires with small guard rings. The configuration of probe respect to the dielectric liquid film is presented in figure S3-2. The readings of these two probes were logged in to the Labview simulator to post-process the acquired data. The schematic of the capacitor circuit used for surface charge density calculation is detailed here. The schematic of capacitor model used for data reduction is depicted in Fig S3-2.

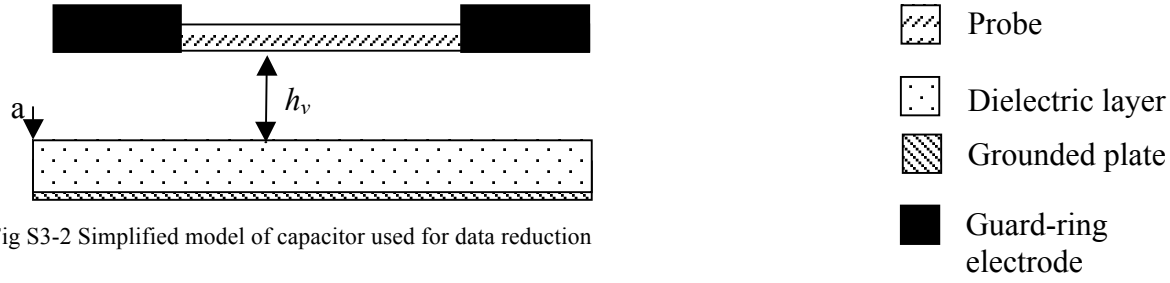

Fig S3-2 Simplified model of capacitor used for data reduction

The voltmeter makes an electric field E_m equal but opposite to the surface electric field in the gaseous side E_g. This corresponds to measured voltages of $v_{measured}$. The electrostatic voltmeter increases the voltage of conductive field probe to necessary values to nullify the electric field between the probe and the surface of interest. This field-nulling condition is achieved when the voltage on the probe matches the unknown voltage on the surface of interest:

$$E_g = E_m$$

$$v_{measured} = E_m h_v$$

$$aE_a + h_v E_g = v_{measured}$$

$$\varepsilon_o E_a - \varepsilon_g E_g = \rho_s$$

$$E_a = \frac{\varepsilon_g v_{measured} + h_v \rho_s}{a\varepsilon_g + h_v \varepsilon_o}$$

$$\rightarrow \rho_s = \frac{\varepsilon_o v_{measuered} - a\rho_s}{a\varepsilon_g + h_v \varepsilon_o}$$

In order measure the surface charge of the oil/liquid interface, similar experimental setup was used and the surface potential was nullified at different corona discharge strengths. The whole diameter of the probe with its guard-ring electrode cover was 0.5 mm. The diameter of the probe was 100 μm. Using guard-ring electrode around the probe minimizes the edge effects and fringing of the electric field.

The surface charge density and potential measurements were performed when the corona discharge was temporarily discontinued. The same measurement technique is widely used to measure the surface charge density and surface potential measurement of electrets pre-exposed to corona discharge (Please see [6-8 of refute document]).

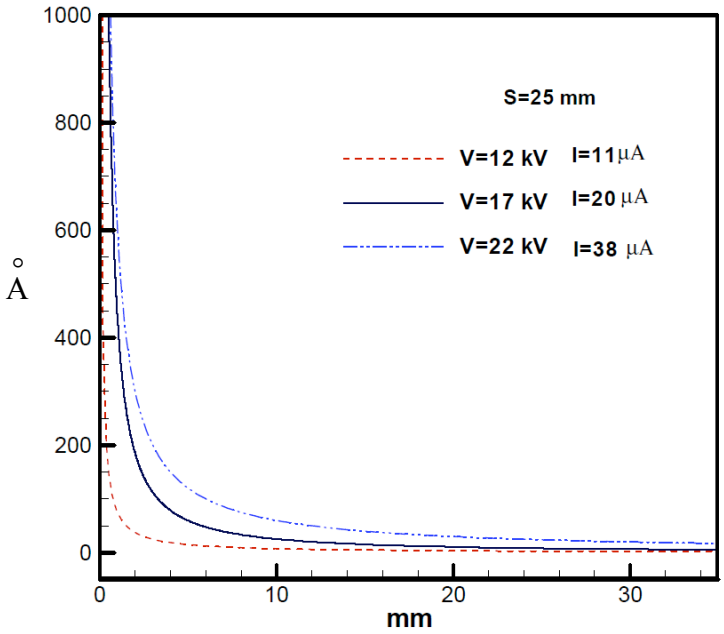

Fig. S3-3 Precursor film profiles of silicone oil droplet obtained by ellipsometry at different corona discharge strength after 2500 min of exposure.

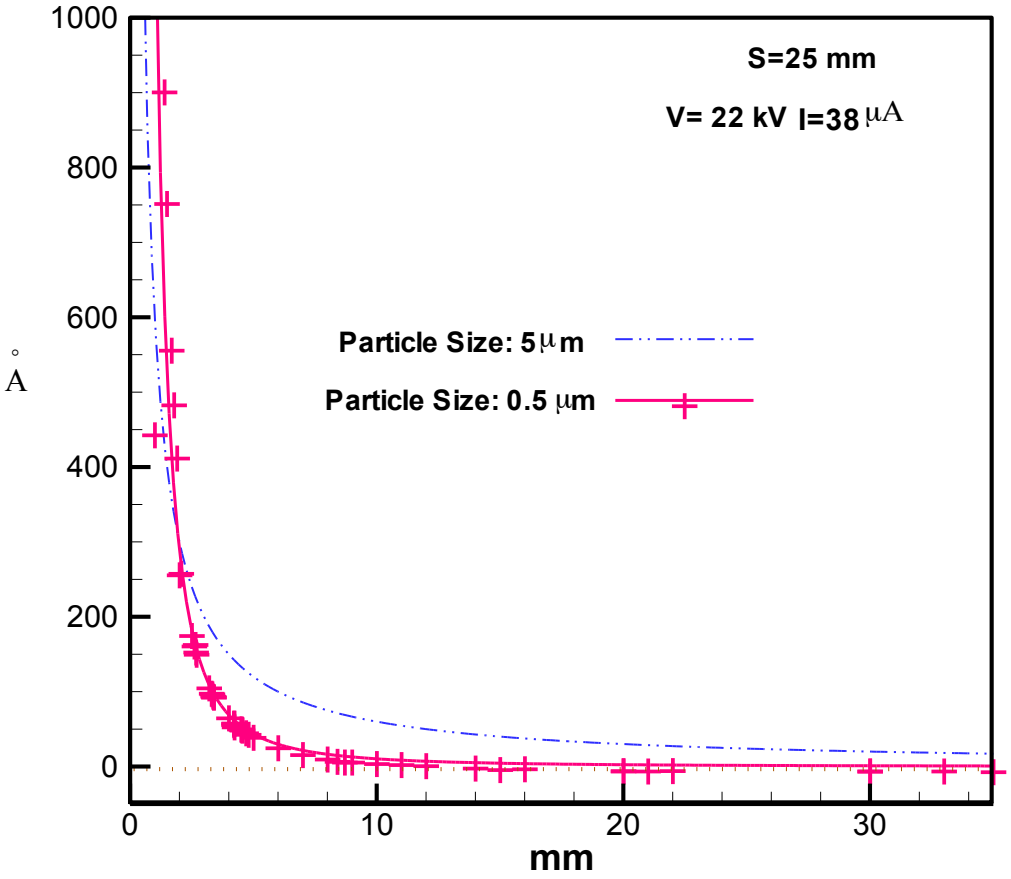

Fig. S3-4 The effect of particle size in spreading of the precursor film with 2500 min of corona discharge exposure.

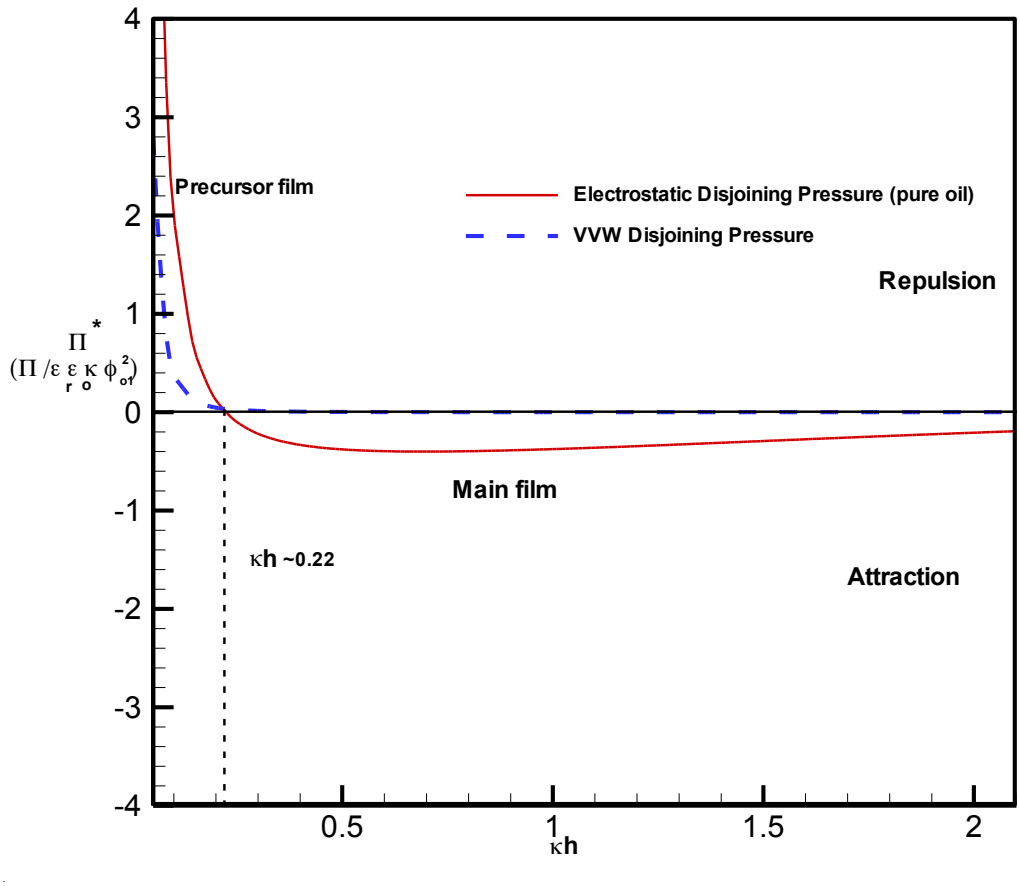

Fig.S3-5 Typical comparison between electrostatic disjoining pressure calculated by eq.(S2-10) and van der Waals disjoining pressure for silicone oil + 1mM AOT solutions. Effective Hamaker constant was considered to be 1×10^{-20} *J*. The corona discharge strength was 22 kV, 38 μA and the size of particles was 5 μm. The surface potentials at the liquid/air and liquid solid were measured to be +120 mV and -72 mV, respectively.