Electrification of water droplets for sustainable energy harvesting

Kayleigh Davies [1,2], Krister Thuresson [1,2], and Vitaly Kocherbitov [1,2]

[1] Department of Biomedical Science, Malmö University, Malmö SE-20506, Sweden.
[2] Biofilms research centre for Biointerfaces, Malmö University, Malmö, Sweden

kayleigh.davies@mau.se

Solid–liquid electrification—the spontaneous charge separation that occurs when water contacts a solid surface—offers a promising route for renewable energy generation. Although this effect has been known for decades, its practical use has been limited because charge remains limited to the nanoscale electric double layer. However, recent work shows that when water flows as discrete plugs formed by mixing air into a hydrophobic tube, each plug can accumulate substantial charge, producing measurable electric potentials even in millimetre-scale channels. This indicates that natural water flows could be harnessed for power generation if the charging process is optimised.
Using the plug-flow pattern and contact-electrification, we developed an experimental setup that measures both the electrical potential generated as water plugs move through a hydrophobic tube (charging) and the subsequent exponential voltage decay (discharging) that occurs once the water flow stops. In this study, we focus on the charging dynamics. As each droplet moves along the hydrophobic polymer surface, it becomes positively charged while negative ions remain on the tube wall. The positively charged water is collected in an electrically isolated Faraday cup, and the total charge, Q, is determined by integrating the voltage–time signal. Preliminary measurements indicate charge generation on the order of 6.3 nC/mL under the current experimental conditions is achievable.
To understand which parameters govern charge generation in this system, experiments are conducted in which tube material and flow conditions are varied. We examine how properties, such as tube material, tube inner diameter, flow rate, plug size, and contact time affect charge transfer. We also explore how different surface geometries (e.g., flat versus tubular surfaces) may modify the charging of the droplets. At this stage, our measurements primarily demonstrate that reproducible charging curves can be obtained, providing a foundation for analysing how material properties and flow conditions might influence electron transfer and the resulting Q values. As this work progresses, identifying the most influential factors is expected to support a future development of hydrovoltaic systems for energy harvesting and sensing technologies.

Keywords:
Charge separation, contact-electrification

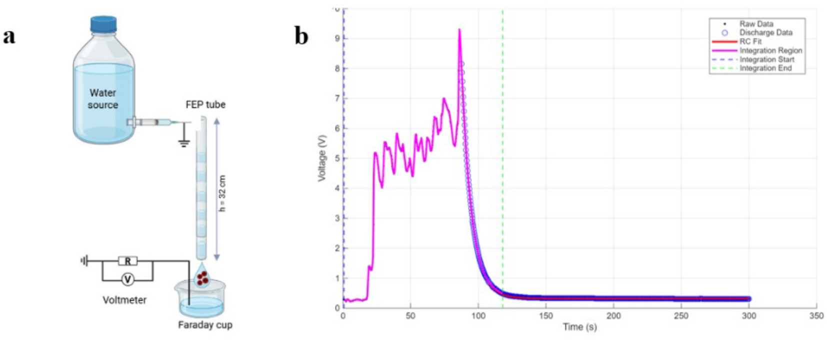

Figure 1.(a) Schematic representation of the experimental setup, (b) a representative voltage–time trace showing the system's charging and discharging dynamics. The total charge generated during the charging phase was 74.4 nC, indicated by the area of the curve in between the dashed lines.

References:

[1] Ao, C.K., et al. *ACS Central Science* . **11** (5), p. 719-733 (2025).