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Technology Offer

Surface Potential and Zeta Potential Measurement via Sliding Drop Electrification

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Abstract

This innovative technology provides a precise apparatus and method to measure surface potential and related physicochemical properties of solid samples. By leveraging the electrical effects of sliding liquid drops on a hydrophobic surface (Fig. 1), the system calculates the surface potential and zeta potential at solid-liquid interfaces. A controlled drop sliding path combined with advanced electrode measurements (Fig. 2) enables accurate and cost-effective characterization of surface properties. Applications span material science, chemistry, and surface engineering, offering a significant improvement over conventional methods that are often complex, costly, or inaccurate.

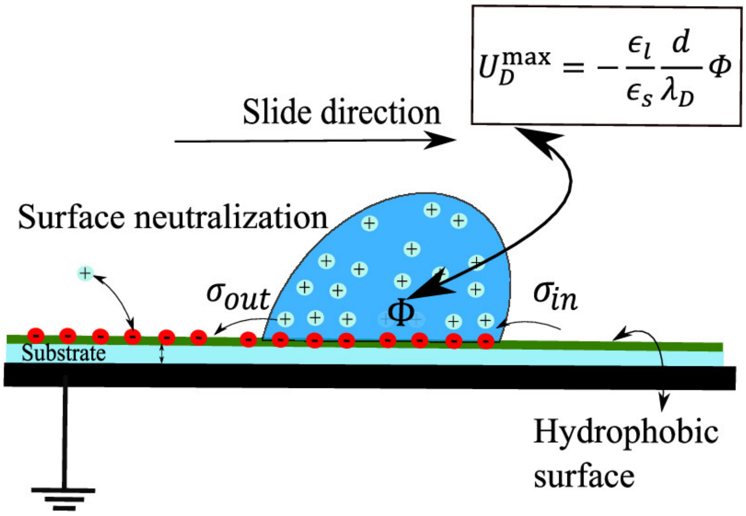

Figure 1: This schematic depicts the charge separation mechanism as a liquid drop slides on a hydrophobic surface. The drop acquires a charge (Φ) while leaving behind a surface charge density (σ_{out}) on the substrate. The equation for U_D^{max} links the maximum drop voltage to parameters such as the substrate thickness (d), Debye length (λ_D), and permittivities (ϵ_l,ϵ_s) Surface neutralization occurs as excess charges are grounded, enabling precise measurement of the surface potential and zeta potential (Bista, et al., 2023).

Background

Surface potential and zeta potential are critical in understanding surface interactions in solid-liquid systems. Traditional methods, such as streaming potential or electrophoresis, are often limited by low precision, high cost, and dependency on specific assumptions. These challenges hinder reliable characterization of materials, particularly under diverse conditions such as varying pH or high salt concentrations. The spontaneous charge separation of moving liquid drops, an effect observed during sliding or dewetting, offers a promising avenue for surface characterization. However, existing techniques lack the precision to quantify this effect directly or translate it into reliable surface property measurements.

Technology

The technology measures surface potential and zeta potential by exploiting the charge separation that occurs when a liquid drop slides over a hydrophobic surface placed on a grounded metal plate. As the drop moves, it collects charge and leaves an opposite charge on the surface. This process is called slide electrification.

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Key parameters are carefully chosen for accuracy (Fig. 2). The slide length ensures charge saturation, balancing drop size and transfer efficiency. The inclination angle (20°–70°, typically 50°) provides stable motion by gravity without disrupting charge separation. Drop volume (0.5–5 mm) affects contact line area and signal strength. Substrate properties like hydrophobicity and dielectric constants influence charge retention; coatings like PFOTS enhance reproducibility. Electrode placement captures the drop's charge at the end of the path, and a quantitative model converts the signal into precise surface potential values incorporating Debye length, dielectric constants, and electrostatic potential equations. This enables precise conversion of measured signals into surface potential values, providing a highly accurate and reproducible method for surface characterization.

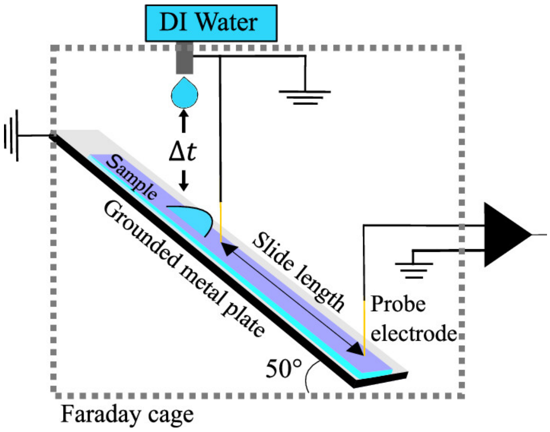

Figure 2: This setup illustrates the measurement of surface potential using a sliding drop. A deionized water drop slides on an inclined, hydrophobic surface placed on a grounded metal plate, acquiring charge as it moves. The resulting electrical signal is measured by a probe electrode at the slide's end (Bista, et al., 2023).

Advantages

- **High Precision**: Direct measurement of surface potential and zeta potential using advanced electrode technology.
- **Cost-Effective**: Reduces dependency on expensive and complex instruments like streaming potential analyzers.
- **Broad Applicability**: Works with various liquids, including polar and ionic solutions, and supports a wide range of surface chemistries.
- **Simplified Setup**: Utilizes basic components like inclined planes, reducing mechanical and operational complexity.
- **Versatility**: Suitable for single or multiple drop measurements, allowing optimization for different sample types and conditions.

Potential applications

- **Material Science**: Characterizing coatings, polymers, and functional surfaces.
- **Chemical Engineering**: Monitoring corrosion, catalysis, and electrochemical reactions.
- **Biological Systems**: Studying membranes, proteins, and other biointerfaces.
- **Industrial Quality Control**: Ensuring consistent surface properties in production processes.
- **Energy Harvesting**: Optimizing triboelectric nanogenerators using charge separation data.

Patent Information

EP23211526.1, 22.11.23

Publications

Bista, P., Ratschow, A. D., Butt, H. J., & Weber, S. A. (2023). High voltages in sliding water drops. *The Journal of Physical Chemistry Letters*, *14*(49), 11110-11116.
Bista, P., Ratschow, A. D., Stetten, A. Z., Butt, H. J., & Weber, S. A. (2024). Surface charge density and induced currents by self-charging sliding drops. *Soft Matter*.

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