ZETA POTENTIAL AS AN INDICATOR OF SOLID SURFACE CHEMICAL PROPERTIES

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Zeta potential analysis

Instrumentation

Litesizer 500
Electrophoretic Light Scattering

SurPASS 3
Streaming Potential
Electrokinetic effects

- Particle dispersions
- Emulsions

- Solid moves
- Liquid stationary
- ELECTROPHORESIS
- Applied Field Causes Movement
- Applied Force Results in Potential
- STREAMING POTENTIAL
- Solid stationary
- Liquid moves

- Solid stationary
- Liquid moves
- ELECTRO-OSMOSIS
- Porous plugs

- Solid moves
- Liquid stationary
- SEDIMENTATION POTENTIAL
- Particle dispersions

Solid surface
SurPASS™ 3 Electrokinetic Analyzer for Solid Surface Analysis

determines the zeta potential on macroscopic solid surfaces
Concept of surface zeta potential

Streaming potential + Streaming current = ζ
Electric double layer

**Diagram: Electric double layer**

- **Potential** $\psi$
- **Immobile layer**
- **Mobile layer**
- **Shear plane**

The diagram illustrates the electric double layer with a potential $\psi$ and an immobile layer adjacent to a mobile layer separated by a shear plane. The distance is shown along the horizontal axis.
Solid surface zeta potential

Surface characterization
– Surface chemistry: acidic and basic functional groups
– Wettability: Hydrophilic / hydrophobic properties

Surface modification
– Chemical and physical surface treatment

Adsorption studies
– Adsorption from the liquid phase on the solid surface
Streaming potential
Streaming potential

\( U_{\text{str}} \)

electrolyte

\( \Delta p \)
Measuring principle

\[ \zeta = \frac{dU_{str}}{d\Delta p} \times \frac{\eta}{\varepsilon_r \times \varepsilon_0} \times \kappa_B \]

\[ \zeta = \frac{dI_{str}}{d\Delta p} \times \frac{\eta}{\varepsilon_r \times \varepsilon_0} \times \frac{L}{A} \]

- \( U_{str} \): streaming potential
- \( I_{str} \): streaming current
- \( \Delta p \): pressure difference
- \( \eta \): viscosity
- \( \varepsilon_r \times \varepsilon_0 \): dielectric permittivity
- \( \kappa_B \): electrolyte conductivity
- \( L/A \): cell constant

Graph:
- Streaming potential \( U_{str} \) vs. pressure difference \( \Delta p \)
- \( R^2 = 0.9999 \)
pH dependence

![Diagram showing the pH dependence of different types of substances: basic, amphoteric, inert, and acidic. The diagram includes the isoelectric point (IEP) for each type and the zeta potential (a.u.) against pH. The graph is labeled with 0.001 mol/l KCl.](image-url)
Single zeta potential

pH 7
0.001 mol/l KCl

-60 -40 -20 0 20 40

chitosan glass chitosan metal oxide

bleached hair

cotton glass

PMMA

PTFE mica

membrane
SurPASS™ 3

The high-end electrokinetic analyzer for fully automated analysis

- Ag | AgCl electrodes: streaming potential, streaming current, cell resistance
- Measuring cell
- External pressure control
- Titration unit
- pH electrode
- Conductivity probe
- Temperature sensor
SurPASS 3 measuring cells

- Adjustable Gap Cell
- Adjustable Gap Cell for Disks
- Clamping Cell
- Cylindrical Cell
- MC for Ceramic Membranes
- MC for Flexible Tubing
- MC for Soft Contact Lenses
- MC for Hollow Fiber Membranes
- MC for 1 ml Pre-Filled Syringes
- MC for Core Samples
SurPASS™ 3 applications

- Membranes and filters
- Biomaterials
- Semiconductors
- Fibers and fabrics
- Cosmetics and detergents
- Minerals
- Polymers
- and many more
Polylelectrolyte multilayer

- PLL | CS multilayer on glass
- PLL .... poly(L-lysine)
- CS ....... chondroitin sulfate
- Polyelectrolyte deposition in 0.025 M HEPES, 0137 M NaCl, pH 7.4
- $\zeta$-analysis in 0.001 mol/l NaCl, pH 5.5

S. Grohmann et al., Biomacromolecules 12 (2011) 1987
SurPASS 3 for semiconductor applications
Self-assembled monolayers: Sensitivity of zeta potential

- SAM of thiols with carboxylic acid and amine terminal groups on gold surface
- HS – (CH$_2$)$_{15}$ – COOH
- HS – (CH$_2$)$_8$ – NH$_2$

Polymer surface activation

- Modification of polyethylene foil thereby retaining bulk properties
- Introducing acidic groups by photochemical process

Polymer surface activation

- Chemical grafting
- Flame treatment
- Plasma treatment
Step-by-Step Process Treatment of Plastic for Semiconductor Applications

Stage 2: Cationic Surfactant Treatment

- More basic, positively charged
- More hydrophilic

Zeta Potential (mV) vs. pH

- Stage 1: 
- Stage 2: Cationic Surfactant Treatment
- Stage 3: 
- Stage 4: 

- Stage 1 Trend
- Stage 2 Trend
- Stage 3 Trend
- Stage 4 Trend
Step-by-Step Process Treatment of Plastic for Semiconductor Applications

Stage 3: H₂SO₄ Treatment

More acidic

More hydrophobic

Zeta Potential (mV) vs. pH

- Stage 1
- Stage 1 Trend
- Stage 2
- Stage 2 Trend
- Stage 3
- Stage 3 Trend
- Stage 4
- Stage 4 Trend
Step-by-Step Process Treatment of Plastic for Semiconductor Applications

Stage 4: Palladium Particle Adsorption (?)

Barely any change from Stage 3

Zeta Potential (mV)

pH

Stage 1
Stage 2
Stage 3
Stage 4
Stage 1 Trend
Stage 2 Trend
Stage 3 Trend
Stage 4 Trend
Particle Adsorption on Silicon Wafer

Adsorption of negatively charged poly(styrene) particles on wafer surface

Wafer cleaning efficiency

SiN ... silicon nitride wafer
SiO ... silicon oxide wafer

Piranha: $H_2SO_4:H_2O_2 = 3:1$, oxidative removal of organic contaminant

HF: removal of silicon oxide
Chemical Mechanical Polishing

- CMP process uses abrasive particles (e.g., Al₂O₃ or SiO₂ slurries)
- After CMP, particles must not adhere to the wafer surface
- Electrostatic repulsion requires equally charged wafer and particle surfaces

(∗ measured by ELS)
Membrane fouling

- Thin-film composite polyamide membrane for reverse osmosis
- Virgin membrane $\zeta$ determined in 0.001 mol/l NaCl
- Adsorption of 100 mg/l humic acid
- Adsorption of 10 mg/l Ca$^{2+}$

I. Owusu-Agyeman et al., J. Membr. Sci. 528 (2017) 82
SurPASS 3 for polymer applications
Antimicrobial coatings

- PET
  poly(ethylene terephthalate) foil
- PET-O$_2$
  PET foil treated with oxygen plasma
- PET-O$_2$-CH
  PET foil treated with oxygen plasma and coated with chitosan

Protein adsorption

- Adsorption of BSA (bovine serum albumin) on titanium
- Isoelectric point (IEP) of titanium | BSA matches IEP of BSA in solution
Monitoring of Adsorption Processes

- Adsorption of poly(ethylene imine), PEI, on silicon oxide wafer
SurPASS 3 for biomaterial applications
Protein adsorption

- Adsorption kinetics of bovine serum albumin (BSA) on glass
- 0.2 mg/ml BSA
- 0.001 mol/l PBS, pH 6.5
Thank you!
Please send your Questions in the Chat Box