

Using the BAT-1 autotitrator to measure the zeta potentials of TiO₂ at different pH

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Zeta potential relies on the chemical composition of the particle surface and the medium environment such as salt concentration and pH. Therefore, a particle system may show various zeta potentials at different pH. Generally, the amphoteric materials tends to carry more positive charges in the low pH range and carry more negative charges in high pH range. The isoelectric point (IEP) is the pH, at which particles carry no net electrical charge and therefore have the lowest electrostatic repulsive force and the worst stability.

The impact of pH on the zeta potential could be interpreted from different aspects. First, the pH affects the dissociation equilibrium of the groups on the particle surface. Secondly, the [H]⁺ and [OH]⁻ concentrations of the solution affect the absorption efficiency of these two ions on the particle surface. At last, the addition of acid or base during titration changes the ionic strength of the dispersion. All these factors should be taken into account when interpreting the titration curves.

In this application note, the zeta potentials of titanium dioxide (TiO₂) at different pH were measured.

Principle

The technology utilized to measure the zeta potential is called electrophoretic light scattering (ELS). In an ELS experiment, a laser beam irradiates the sample, where the scattered light is detected at a forward angle of 12°. The sample solution or suspension is subjected to an electric field applied to both ends of the sample cell, resulting in the electrophoretic movement of the charged particles in the sample. As a consequence, the frequency of the scattered light shifts compared to the incident light due to the Doppler effect. The phase shift of the scattered light signals is calculated by PALS analysis. By the phase plot, the velocity of electrophoretic movement per unit of the electric field, which is denoted as the electrophoretic mobility μ , is obtained. Through Henry's equation, one can calculate the electrophoretic mobility μ and its zeta potential ζ as follow:

$$\mu = \frac{2\varepsilon_r\varepsilon_0\zeta}{3\eta} f(\kappa\alpha)$$

where ε_0 is the solvent dielectric constant in the vacuum, ε_r is the relative dielectric constant, η is the solvent viscosity, $f(\kappa\alpha)$ is the Henry function, K is the reciprocal Debye length, α is the particle radius, and $\kappa\alpha$ refers to the ratio between the thickness of the double layer and the particle radius.

The BeNano 90 Zeta (Bettersize Instruments Ltd.) was used for the zeta potential measurement in this application note.

Experimental

The TiO_2 powder was dispersed in pure water and stirred for 15 min with a magnetic stirrer. The initial pH is 5.4 and the corresponding zeta potential is negative. The titration is performed automatically from pH 5.4 to 2 with HCl titrant by the BAT-1 autotitrator, and the pH interval and the tolerance are set to 1 and 0.2, respectively.

The zeta potentials are measured with the folded capillary cell by the BeNano analyzer at the default temperature of $25^\circ\text{C} \pm 0.1^\circ\text{C}$ controlled by the built-in temperature control system.

A single zeta potential measurement was performed at each target pH.

Results and discussion

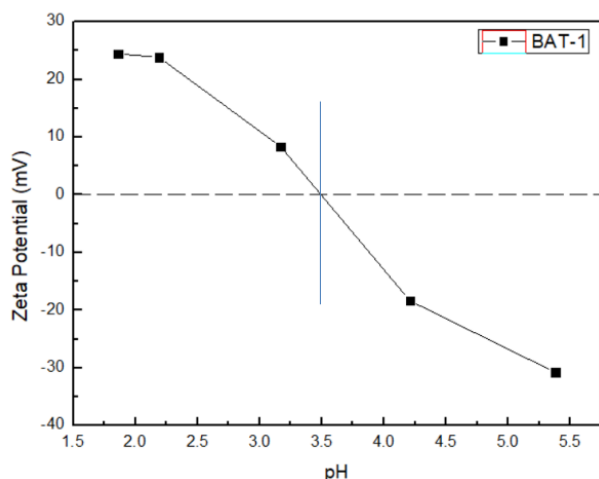


Figure 1. The zeta potential curve at different pH

Figure 1 shows that the zeta potentials of TiO_2 are positive in the low pH range, which indicates there are many positive charges on the particles. With the increase of pH, the zeta potential gradually approaches 0mV and the dispersion reaches the isoelectric point at pH3.5. With the further increase of pH, the particles begin to carry negative charges, and the magnitude of zeta potential gradually increases. When there are more charges (either positive or negative) on the particles, the magnitudes of the zeta potentials of the dispersion are higher, which illustrates that the system tends to be more stable and less likely to form aggregates.

Conclusion

The BeNano with PALS (phase analysis light scattering) technique can effectively measure the sample with low electrophoretic mobility. Accurate zeta potentials can be obtained even within the potential range of ± 10 mV, which is very important for confirming the isoelectric point of the system. The combination of BeNano and BAT-1 significantly simplifies users' operation, improves titration efficiency, and reduces workload.

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