Capillary Surface Modification for Improved Electroosmotic Flow and Green Anion Analysis in Food Applications

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Abstract

Capillary electrophoresis (CE) coupled with capacitively coupled contactless conductivity detection (C^4D) is a powerful platform for rapid ionic analysis, offering high separation efficiency, low reagent consumption, and minimal waste generation. However, CE performance, particularly for anion analysis, depends strongly on electroosmotic flow (EOF). Conventional reversed-EOF systems commonly rely on CTAB-modified buffers, but dynamic surfactant adsorption can cause EOF instability, migration-time variability, and frequent capillary reconditioning. This seminar presents capillary surface modification as an alternative strategy to improve EOF control and enhance CE-based anion separation. Emphasis is placed on amine-based surface modifications, including aminopropyl (APTES) functionalization, polymer-assisted coatings, and hybrid polydopamine–cationic polymer layers. These modified surfaces provide stable or tunable reversed EOF, improve migration-time reproducibility, and enhance coating durability compared with conventional CTAB dynamic systems.

The developed CE-C^4D systems enabled rapid separation of complex mixtures of food-related anions in approximately 10 minutes and were successfully applied to beverage and food samples using simple aqueous extraction or dilute-and-shoot preparation. The approach reduces solvent use, simplifies sample preparation, and delivers reliable sensitivity, linearity, precision, and recovery in complex matrices. Brief examples of complementary miniaturized platforms, including microwell, headspace, and microtube assays, will also be introduced to illustrate the broader integration of surface chemistry, miniaturization, and green analytical design for sustainable food analysis.