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Controlling Trajectories of Iron oxide Nanoparticles by Free-flow Electrophoresis for Bioapplications

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Superparamagnetic iron oxide nanoparticles (SPIONs) possess distinctive magnetic properties that arise from their nanoscale dimensions and superparamagnetic behavior. These characteristics make them exceptionally suitable for a broad spectrum of biomedical applications. However, the full potential of SPIONs relies on the ability to precisely manipulate their movement and separation in continuous flow systems. This study explores the use of Free-flow Electrophoresis (FFE) as a versatile tool for controlling the trajectories of functionalized SPIONs based on their electrophoretic mobility.
The cornerstone of this study is a predictive model designed to precisely control and predict the trajectories of functionalized SPIONs within a Free-flow Electrophoresis (FFE) system. This framework is applied to optimize two high-precision bio-applications: enantioseparation and cancer cell diagnostics. In enantioseparation, chiral selectors on the SPION surface enable the separation of enantiomers based on their differing electrophoretic mobilities. In diagnostics, antibody-conjugated SPIONs target malignant cells, such as the HT-29 line, for continuous isolation. Critically, the FFE system serves as an essential clean-up stage by removing unbound nanoparticles that would otherwise cause signal interference, ensuring high-purity separation and more accurate downstream analysis. This synergy between trajectory modeling and FFE purification provides a robust platform for advanced diagnostic and preparative biomedical tasks.

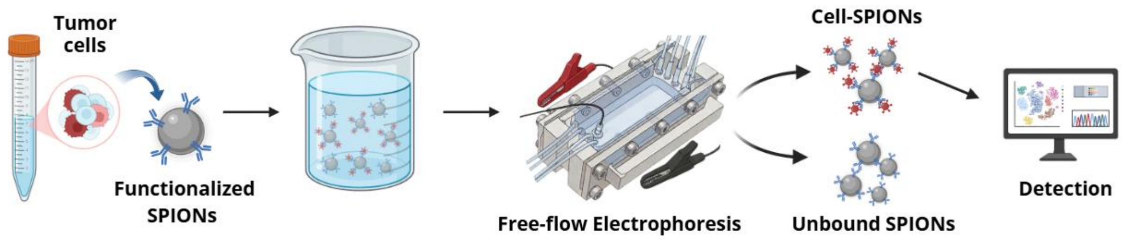

Figure 1: Schematic workflow of the FFE-mediated diagnostic platform.