A Closed-loop, Non-linear, Miniaturised Capillary Electrophoresis System Enabled by Control of Electroosmotic Flow

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The miniaturisation of capillary electrophoresis (CE) systems makes separation of ionic species with similar electrophoretic mobilities challenging. We report on a novel closed-loop system that does not rely on migration time to identify ionic species unlike many conventional CE systems. To aid miniaturisation our method requires the sample undergoing separation to travel back and forth along the short channel multiple times. For each consecutive cycle the sample becomes increasingly separated until it is deemed sufficiently separated such that it can be reliably identified by any appropriate detection system. As the sample approaches either of the channel ends, contactless conductivity detectors detect the presence of the sample and trigger the modification of the electroosmotic flow (EOF) to reverse the direction of flow in the channel. After sufficient separation the identification is performed in-channel using, in our case, an electrochemical detection scheme. Incorporation of a closed-loop control system means that unpredictable variation in migration time does not present an issue for ionic species identification. This new method of non-linear CE is demonstrated in a microfluidic channel formed in PDMS (polydimethylsiloxane), reversibly sealed to a glass wafer on which metal electrodes are patterned in gold. The sample movement in both directions along the channel occurs without affecting the electrophoretic separation already achieved during each cycle by changing the EOF in magnitude and direction. The EOF is changed by modifying the zeta-potential along the channel wall through the application of a voltage on a zeta-potential modification (ZPM) electrode placed close to the channel surface. Depending on the magnitude and polarity of the voltage applied to the ZPM electrode our experiments have shown the ability to increase, decrease or reverse the EOF.