Miniaturized High-performance Liquid Chromatography (HPLC) System Using Capillary-scale Electrokinetic Micropumps

Kamlesh D. Patel and Robert Crocker
*Sandia National Laboratories, 7011 East Ave., Livermore, CA 94*551

Micropumps for microfluidic applications have received a great deal of recent interest because they can reduce the system size, reagent volumes, and power requirements for fluid manipulations and actuate microscale moving parts, making inexpensive micro- and portable-chemical analysis systems feasible. Electrostatic, thermopneumatic, and piezoelectric style micropumps are limited to a maximum pressure of about 100 KPa (14.5 psi). On the other hand, electrokinetically driven pumps are capable of delivering extreme high pressures (690 MPa or 100 kpsi). Such pumps have been demonstrated as microhydraulic actuators and micro-HPLC pumps. EK micropumps developed at Sandia National Laboratories are less than half centimeter in diameter and a few centimeters long; they can be fabricated as an inline pump in a microchannel or as an external module. These silent EK pumps generate fluid flow when a voltage gradient is applied. Electrokinetic (EK) micropumps are well suited for pressure-driven flow in microfluidic systems, particularly micro-HPLC. The pumps are physically compact, operate silently, and generate hydraulic work with no moving parts. EK pumps use electroosmosis in a charged nanoporous (10-500 nm) media to generate pressure and flow. An applied axial electric field causes migration of solvated ions at the double layer near the charged solid interface and results in viscous drag of the bulk fluid. Pressure and flow generated by an EK pump vary linearly with the applied electric field, which facilitates control.

In our research to develop a micro-HPLC using EK-pumping technology, we have developed robust and simple EK pumps in fused-silica capillaries with densely packed sub-micron silica particles. EK pumps with basic buffers have demonstrated highly reproducible flow rates from nanoliters to microliters-per-minute over tens of hours at high pressures. Pressures as high as 50,000 psi (3,450 bar) have been demonstrated with a 500-V/cm field strength. We have optimized EK pumps to precisely deliver solvents for high-pressure liquid chromatography in 75 µm I.D. x 100 mm long capillary columns. The compact EK-HPLC system delivers two solvents without flow splitting for isocratic and binary gradient separations. Isocratic separation of small molecules shows excellent reproducibility. Flow rate precision of 1% RSD is achieved with flow control using differential pressure feed-back. EK pump performance, flow stability, and gradient control with our miniature HPLC system will be presented. Example isocratic and gradient separations of small molecules and peptide standards using our EK-HPLC will also be presented.