360e A New Electroosmotic Pump and Its Applications

Ping Wang, Zilin Chen, and Hsueh - Chia Chang

A high-pressure electro-osmotic micro-pump fabricated by a sol-gel process is shown to be potentially effective as a fluid-driving unit on chip-scale analytical systems, particularly for chip-scale high-performance liquid chromatographs whose substrate packing produces considerable hydrodynamic resistance. A silica monolithic matrix with micron-scaled through-pore morphology was synthesized within the 100 µm i.d. fused-silica capillary through a sol-gel process. The monolith bonds directly with the capillary inner wall such that frits with large pressure loss are unnecessary. This pump uses electroosmotic (EO) flow to propel liquid solution with no moving parts. Altering the sol-gel chemistry enables the porosity and physical properties of silica monoliths to be tailor-designed. The micron-sized through-pore of the substrate has a dimension roughly comparable to the double layer thickness of many organic liquids. Because the monolith is derived from liquid phase, therefore the entire cross-section of the pore is charged and with the maximum possible number of charges. Maximum Maxwell force hence results to sustain a high pressure. A Nafion® housing design in the cathode chamber prevents flow leakage into the electrode reservoir from the flow channel and hence maximizes the pressure build-up. It also eliminates electrolytic bubble interference from the flow channels and provides ionic channels for current penetration simultaneously. As the monolith is silica-based, this pump can be used for a variety of fluids, especially for organic solvents such as acetonitrile and methanol, without swelling and shrinkage problems. The maximum flow rate and maximum pressure generated by the 100 µm i.d. monolithic pump are 2.9 µL/min and 4 atm respectively, for deionized water at 6 kV applied voltage. As a large fraction of the small current (pico-amps) is due to convection, a precise instantaneous measure of the flow rate can be obtained from current measurement. Hence, precise flow control can be implemented on the chip with minimum micro-circuitry. Bubble generation, which is a common problem for other DC pumps, was not observed even at these high-voltage and high-pressure conditions. Design (pressure-voltage and flow rate-voltage) correlations are obtained for a rich variety of working fluids and for different pump porosity, dimensions and loads. These pump curves are shown to collapse a large number of measured data for four solvents with different permittivity and conductivity that varies over several orders of magnitude.

The pump was demonstrated to be effective and robust for micro-fluid injection analysis (µ-FIA) as a fluid-driving unit. The micro FIA system consists 7.5 cm), a×of a monolithic micro-pump on a glass slide (2.5 cm 1.5 cm). An electro-active×micro-injector and a micro-sensor (2.5 cm neurotransmitter, dopamine, was used as the test sample. Chronoamperometric measurement of dopamine oxidation on microchip sensor verified the applicability of the monolithic pump. In addition, we also demonstrated that, by changing the polarity of the electrodes, the same electric potential was harnessed to generate a stable electrospray (ES) electrostatically directly from the porous emitter without the assistance of an upstream micropump. Characterization of the electrospray process by optical and electrical monitoring was carried out. Four typical spray modes were obtained depending strongly upon the coupling between the micropump and electrospray. Therefore, a fully integrated EO/ES coupling system was realized.