

Tuning Magnetoconvective Flow in a Redox-Magnetohydrodynamic Microfluidic System

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Miniaturization of chemical analysis brings a favorable decrease in the amount of resources, power, and time required by the analytical procedure, but the development of a miniaturized analytical device is a complex and multifaceted issue. For instance, micro total analysis systems (μ TAS) containing fluid elements require a microfluidic pumping method compatible with the device and the analysis to be performed. Our work expands the applicability of redox-magnetohydrodynamic (MHD) pumping to microfluidic systems by exploring patterns of magnets and electrodes for fluid flow profiles without channels; in particular we are interested in mixing and catalytic applications. Redox-MHD, a relatively new magnetoelectrochemical pumping method, is a promising and advantageous addition to the microfluidics repertoire: it requires no mechanically moving parts, simplifying device fabrication; the flow is multidirectional, programmable, and has a flat velocity profile, allowing modularity and more precise system control; and there is no electrode degradation, solvolysis, or high overpotentials which have been complications for some other electrochemical pumps (1, 2).

The "MHD force" vector \mathbf{F}_B which propels a fluid body in redox-MHD arises from the movement of charged particles (e.g., solvated ions) in a magnetic field, following the relationship $\mathbf{F}_B = \mathbf{j} \times \mathbf{B}$ where \mathbf{j} is the body's ionic current density and \mathbf{B} is magnetic flux density. With few exceptions (3, 4), redox-MHD has traditionally been studied near electrodes in solution, perhaps because of the ease of modeling \mathbf{j} from a small electrode. In contrast, we have shown localized, reversible redox-MHD flow in bulk solution several mm from diffusion layers at active electrodes. This significant result indicates the power of redox-MHD to produce fluid flow at arbitrary locations in an electrochemical cell based on the pattern of electrodes and magnets which produce \mathbf{j} and \mathbf{B} . The major innovation has been the use of a magnet much smaller than the electrochemical cell, effectively localizing \mathbf{B} to the site where fluid control is desired; our work emphasizes the ability to "tune" both terms in order to achieve interesting and useful flow profiles.

Redox-MHD has previously been used to transport a sample plug from an injection port to an analytical site in a microfluidic device (5). The separation of fluid flow from electrochemical processes at active electrodes allows such a procedure to be performed without any interference from redox species, an ongoing study in collaboration with our own. By tuning \mathbf{j} and \mathbf{B} , redox-MHD fluid flow can manipulate a sample in other ways; in particular we will discuss the possibility of combining arbitrary fluid elements for catalytic applications, as well as of introducing turbulence into the fluid for mixing applications (in the form of high Reynolds numbers).

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