

Redox-magnetohydrodynamic (RMHD) Pumping with PEDOT-Modified Electrodes

Christena K. Nash and Ingrid Fritsch

University of Arkansas

Department of Chemistry and Biochemistry
Fayetteville, AR 72701

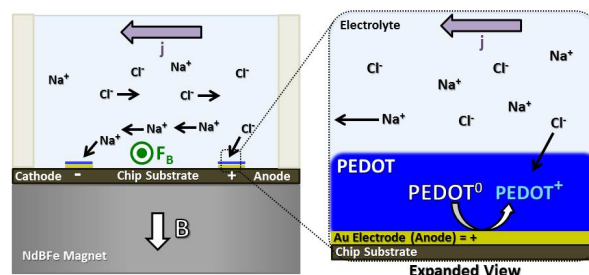
The miniaturization of analytical techniques has been the trend during the last couple of decades as evidenced by the rise in publications dealing with lab-on-a-chip (LOAC) applications. LOAC applications are attractive because less energy and sample and reagent volumes are consumed (1). LOAC systems require microfluidic pumping for reagent introduction, mixing, separation, and detection.

Redox-magnetohydrodynamics (RMHD) is a relatively new microfluidic pumping technique that offers complementary features and advantages over existing microfluidic approaches. RMHD is compatible with aqueous and non-aqueous solutions, is capable of generating high currents with low applied voltages, does not require channels or moving parts, can stop or switch direction of flow with ease, and allows for fine-tuned fluid manipulation through careful design of electrode geometries and programming of active electrodes (2-3). RMHD takes advantage of fluid flow produced by a body force, F_B , which is defined by a simple right hand rule: $F_B = \mathbf{j} \times \mathbf{B}$, where the ionic current density, \mathbf{j} , is generated through oxidation or reduction of redox species at electrode surfaces in the presence of a perpendicular, externally-applied magnetic field, \mathbf{B} (4-6).

The addition of redox species in solution can generate high currents while keeping applied voltages low. However, in lab-on-a chip applications the addition of redox species could interfere with the detection of analyte and could degrade biological species, although low concentrations have been shown to be compatible with heart tissue (7). To minimize the risk of possible interfering reactions, conducting-polymer-modified electrodes were used to generate \mathbf{j} , thereby confining redox species to the electrode surface, separating them from the sample.

The conducting polymer poly(3,4-ethylenedioxythiophene) (PEDOT) was electropolymerized on long, parallel microband gold electrodes (100 μm wide and 2.5 cm long) on a silicon microarray chip. Electropolymerization was done by immersing the microarray chip in aqueous solution containing 0.01 M of the monomer, 0.01 M sodium dodecyl sulfate, and 0.1 M potassium chloride and then cycling the potential (between -0.455 V to +1.125 V) to oxidize the monomer (8-9). The dark blue, uniform PEDOT films showed a large charge capacity and good electrochemical stability.

A 620 μm thick polydimethylsiloxane gasket (with a rectangular opening of 1.5 cm X 3.2 cm) was placed on the chip to form the walls of the microfluidic cell. A solution of 0.1 M sodium chloride containing 10 μm polystyrene beads was added to the cell and a glass slide was placed on top to form the ceiling. The chip was placed on a permanent NdFe disk magnet with a \mathbf{B} -field of 0.37 T. Fluid velocities were determined by tracking the movement of the beads using video microscopy and particle imaging velocimetry analysis.



Right shows distant view of the PEDOT film, oppositely biased electrodes, magnet location, and expected fluid flow. When a potential is applied to the electrodes, anions must come in and out of the PEDOT film to compensate for the change in charge. Left shows expanded view of the PEDOT film on the anode. As PEDOT is oxidized, anions (Cl^-) must come into the film.

When a potential was applied, high currents (and therefore high fluid velocities) were observed initially, but quickly decreased to zero as the PEDOT film was converted. The film must then be converted back to its original oxidation state to generate any more fluid flow in the same direction. By applying a current, the time sufficient fluid flow can be observed was extended and the fluid velocity was controlled, which could be valuable for adjusting the fluid velocity to meet the requirements of a given application.

In the work described, flow generated by applied potential and applied current to PEDOT-modified electrodes and methods for regenerating the film while continuing to pump will be discussed.

ACKNOWLEDGEMENTS

Research was supported through the National Science Foundation (NSF) (CHE-0719097) and the Arkansas Biosciences Institute, the major research component of the Arkansas Tobacco Settlement Proceeds Act of 2000.

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