547d Engineering of Mass Transfer Boundary Layers in Laminar Flow-Based Microreactors

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Taking into account the characteristics and transport phenomena of the microscale is a common feature of all research in microchemical systems. The inherently short distances lead to the potential for short residence times and fast heat and mass transfer compared to the macroscale. The occurrence of laminar flow and the capability to create laminar flows consisting of multiple streams each containing different chemistries is the key microscale characteristic being utilized in this work. The dimensions and operating conditions of the proposed electrochemical microreactors are such that fluid flow is pressure driven and characterized by a Reynolds number, Re, less than 10. Two or more different liquid streams introduced into the same channel at Re <~2100, will proceed to flow laminarly in parallel as the viscous effects dominate over the inertial effects. In this work, electrochemical conversions are being explored in a microreactor in which electrodes line opposing, inside walls of a microfluidic channel. Pressure-driven laminar flow allows for two streams of different composition to be guided over each of these electrodes respectively, without the need for a physical barrier. The two mass transfer related physicochemical phenomena that determine performance for this novel microreactor concept are (i) slow mixing by interdiffusion of the two stream at the liquid-liquid interface and (ii) the formation of reaction-induced depletion boundary layers on the electrodes. For optimal performance (i.e. high conversion rates) of the microreactor, control of the concentration boundary layer is important. Minimization of its thickness will create a steeper concentration gradient and thus drive a larger flux of reactants through the depletion region to the electrode. Once the limits of minimizing the thickness of the boundary layer have been exhausted, one can manipulate the concentration boundary layer to increase the performance of the electrochemical microreactor. This presentation will cover tow different approaches: First, one can modify the microreactor design to have multiple inlets or outlets to add fresh reactants or remove depleted boundary layer respectively. This approach is to enhance the diffusion of the reactants to the surface either by adding fresh reactants to the surface or by removing the depleted zone via adding multiple inlets or multiple outlets. Another or additional way to increase mass transfer to the electrode is the introduction of a chaotic micromixer based on herringbone ridges, as described by Stroock et al. Use of this micromixer concept to continuously replenish the concentration boundary layers on the electrode of the microreactor --thereby increasing the conversion rates-- will also be presented.