171i Empirical Validation of the Hydraulic Design of a Silicon Carbide Micro-Channel Reactor for the Si Process

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The Sulfur-Iodide (SI) process has been investigated extensively as an alternate process to generate hydrogen through the thermo-chemical decomposition of water. The commercial viability of this process hinges on the durability and efficiency of heat exchangers/decomposers that operate at high temperatures under corrosive environments. In cooperation with the DOE and the University of Nevada, Las Vegas (UNLV), silicon carbide (SiC) based micro-channel decomposer concepts are being developed and tested. The performance benefits of a high temperature, micro-channel heat exchanger are realized from the thermal efficiency due to improved effectiveness of micro-channel heat and mass transfer and the corrosion resistance of the ceramic materials. As part of this development, numerical models and empirical testing were used to characterize the flow within the network of micro-channels. The computational fluid dynamics (CFD) work is reported elsewhere. Within this paper, the experimental methods and results are discussed. Micro-channel devices are extremely efficient in transferring heat and mass due to the small length scales (10-5 to 10-3 meters) over which the transport phenomena occurs. This intensification reduces the residence time of the process fluids in the “reactor zone” in the micro-channel device. However in order to scale up to commercial processes, these highly efficient micro-channels must be ganged together in an array of parallel and/or serial flow paths. This simulates the evolution of the micro-electronics industry where computational performance has improved several orders of magnitude through decreasing the length scale, enabling faster clocks speeds and by arranging CPU's in parallel, enabling higher throughputs. Typically, large numbers of parallel flow channels has lead to mal-distribution, leading to inefficient performance due to stagnant regions while other regions are over saturated. The spatial pressure profile was mapped by integrating pressure sensitive films into the micro-channel walls. Given these pressure distributions and the overall flow rate of the system, the relative flow rates of each channel could be deduced from a series of Bernoulli equations relating the velocity (mass flow rates) to the differential pressures. These results are then correlated to the CFD analyses as they relate to the optimization of the micro-channel array and the gas distribution manifolds.