Effect of Catalyst Segmentation with Cavities on Combustion Enhancement of Multi-Fuels in a Micro Channel

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Abstract

Hydrocarbon-fueled micro-reactors have received increased attention as a potential means of energy conversion for electrical power generation in portable electronics due to their superior energy density compared to that of state-of-the-art lithium batteries [1]. Conversion of chemical energy of fuels into electricity in a microscale device without moving parts can be achieved by using fuel cells, photovoltaics [2] and thermoelectrics [3]. A major obstacle in creating practical micro-reactors (with characteristic dimension < 1 mm) is their enhanced heat loss and combustion instability. Homogeneous flames are typically quenched when confined in spaces with dimensions below their quenching distances [4]. The associated large surface-to-volume ratio of the micro-reactor calls for the potential applications of the heterogeneous conversions and the heterogeneous catalytic combustion in a micro-reactor received intensive research attentions recently [5, 6]. Complicated heterogeneous-homogeneous interactions can be observed in the microreactors. Well-know aspects of interactions include the promotion of gas-phase reactions due to the catalytically induced exothermicity and the inhibition of gaseous reactions due to the competition of fuels and oxidizers by the catalyst bed. This competition between heterogeneous and homogeneous reaction often leads to incomplete combustion and narrowing of the stable operating range. Therefore, some strategies were proposed to implement in micro-reactors, such as heat recuperation [7] and utilizing quench-resistant fuels [8]. Pertinent design of combustor configuration and catalyst bed can result in improvement of reaction and heat and radical loss in the reactor. Federici et al. [7] demonstrated that the thermal properties of reactor materials play a vital role in the overall thermal stability of micro-reactor. The reactor walls not only account for the heat loss

through conduction, but they are often responsible for the majority of the heat transfer from upstream, which is necessary to preheat the feed to ignition temperature. In other words, a proper manner to maintain high wall temperature in localized space can extend gas reaction and mitigate radical quenching. Moreover, Norton and Vlachos [8] report that adding hydrogen can successfully induce self-ignition of propane/air mixtures (gas reaction) in the microreactor with capitalization on the heterogeneous reaction of hydrogen. Accordingly, when burning the multi-fuels of carbon monoxide and hydrogen blending with hydrocarbon in a catalytic micro-reactor will definitely exhibit complicated hetero- and homogeneous reaction based on their different diffusive and catalytic characteristics. Nevertheless, the interplay of kinetics and transport of multi-fuels reactions in the catalytic micro-reactors is scarcely studied in the past.

Keyword：Catalyst segmentation, Micro channel, Multi-fuels