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Multi-Functional Structured Catalysts For Clean Exhaust from Lean Burn Vehicles

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The U.S. faces the difficult dual challenge of reducing the consumption of transportation fuels and improving air quality. Lean burn gasoline, diesel, and natural gas engines are of interest because they are more fuel efficient than conventional stoichiometric gasoline engines. Unfortunately, the unconverted oxygen in the exhaust prevents the use of the conventional three-way catalytic converter to reduce nitrogen oxides ("NO_x") to N_2. To take advantage of the increased fuel efficiency of these vehicles while improving urban air quality, significant reductions in the emissions of NO_x and particulate soot (in the case of diesel) are needed. Two technologies have emerged to achieve the stringent NOx emission regulations, *NO_x Storage and Reduction (NSR)* and *Selective Catalytic Reduction (SCR)*. NSR is a promising but complex catalytic process that involves the sequential periodic reactive trapping of NO_x and its rapid reduction on multi-functional catalysts containing precious metal and storage components. SCR is adopted from the stationary source process which utilizes NH_3 as the NOx reductant, and utilizes both Cu- and Fe-exchanged zeolite catalysts. As stand-alone reactors, NSR has the noted disadvantage of cost (precious metal) and byproducts (NH_3, N_2O), while SCR requires an aqueous urea system to provide the NH_3, which may "slip" from the reactor under the inherent transient vehicle operation. Moreover, both NSR and SCR have constrained temperature operating windows (low and high). Multi-functional catalyst architectures that combine two or more active layers or zones can be effective strategies to address cost and/or performance limitations. In this talk we describe several examples from our recent experimental and modeling studies of three different multi-functional structured catalysts. The first combines Fe- and Cu-exchanged zeolitic layers to expand the high NOx conversion temperature range. The second "NSR + SCR" catalyst combines periodic NOx storage and reduction with in situ NH_3 generation and selective catalytic reduction of NOx. The third "*Ammonia Slip Catalyst*" (ASC) combines an ammonia oxidation catalyst and a metal-exchanged zeolite as a NOx reduction catalyst in a dual-layer architecture to oxidize NH_3 with high selectivity to N_2. We show how focused experiments complemented by modeling can not only lead to deeper insight but also to "optimal" structures and operating strategies.