# Impact of Axial Catalyst Configuration on the Performance of Coupled LNT-SCR Catalysts Studied by Spatiotemporal Resolution of Reactions

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## Introduction

Recently, the concept of coupled LNT and SCR catalysts has been introduced to the automotive NO<sub>x</sub> control community in order to achieve higher NO<sub>x</sub> conversion than is possible with stand-alone LNTs. Besides enhanced NO<sub>x</sub> conversion, combining SCR and LNT catalysts offers other performance advantages such as lower N<sub>2</sub>O slip and reduced catalyst cost due to lower precious metal loading [1,2]. Several LNT-SCR configurations have been proposed including sequential (LNT brick + SCR brick), sandwiched (multiple alternating LNT-SCR bricks), double-layer (one brick with an SCR washcoat on top of an LNT washcoat), and mixed (one brick with one washcoat layer of physically mixed LNT and SCR catalyst particles) [2]. In this study, we measured the spatiotemporal distribution of reactions along two different LNT-SCR catalyst configurations (sequential vs. sandwiched) to better understand the interplay between LNT and SCR components under lean/rich cycling conditions. Specifically, we assessed the impact of changes in reaction distribution on NO<sub>x</sub> reduction performance.

## Materials and Methods

A low Pt/Rh and medium Ce loaded LNT catalyst and a commercial SCR catalyst based on Cu-chabazite zeolite were evaluated in a bench flow reactor. The two catalyst configurations studied were 1.5" LNT + 1.5" SCR and 0.75" LNT + 0.75" SCR + 0.75" LNT + 0.75" SCR; both configurations were composed of the same LNT and SCR monolith cores. A quadrupole mass spectrometer (Pfeiffer) and a high-speed FTIR gas analyzer (MKS) were used for spatiotemporally resolved gas analysis. The catalyst was studied under conditions relevant to coupled LNT-SCR applications: Lean (60 s) – 500 ppm NO, 8% O<sub>2</sub>, 5% H<sub>2</sub>O, 5% CO<sub>2</sub>, N<sub>2</sub> balance; Rich (5 s) – 2.5% H<sub>2</sub> (with or without 278 ppm C<sub>3</sub>H<sub>6</sub>), 5% H<sub>2</sub>O, 5% CO<sub>2</sub>, N<sub>2</sub> balance. NO<sub>x</sub> reduction performance was evaluated over 200-400 °C. Spatiotemporal profiles of gas concentrations were measured at 1L (outlet), 0.75L, 0.5L, 0.25L, and 0L (inlet) locations.

#### **Results and Discussion**

As shown in Figure 1, the results confirm the positive impact of adding an SCR catalyst to an LNT catalyst with respect to  $NO_x$  conversion over the entire temperature range. As reported in the literature, the additional  $NO_x$  conversion was achieved through reactions over the SCR catalyst between  $NO_x$  and  $NH_3$  slipped from the LNT catalyst. Very similar outlet conversion levels were achieved for both LNT-SCR and LNT-SCR-LNT-SCR configurations under the conditions used in this study. While  $NO_x$  conversion over the LNT sections was significantly higher at 400 °C than 300 °C (compare for instance conversion levels at 0.25L location in Figure 1), the overall outlet conversion was the highest at 300 °C. This is likely due to greater  $NH_3$  generation from the LNT and higher subsequent storage on the SCR catalyst at 300 °C;  $H_2$  was not effective in reducing  $NO_x$  over the SCR catalyst. Adding 278 ppm  $C_3H_6$  to the rich feed (resulting in 10% increase in total reductant) at 400 °C

increased LNT  $NH_3$  slip, but the increased amount was not enough to significantly impact the  $NO_x$  conversion over the SCR catalyst bricks.

A major difference between the sequential and sandwiched configurations observed in this study was the N<sub>2</sub>O yield at 200 °C, a considerably lower value being obtained for the sandwiched configuration (Figure 1). The data show that most of the N<sub>2</sub>O was generated over the LNT catalyst. In the case of the sequential configuration, more N<sub>2</sub>O was generated over the  $2^{nd}$  LNT section (0.5L) than over the  $1^{st}$  LNT section (0.25L) (Figure 1a). Furthermore, the N<sub>2</sub>O produced over the  $2^{nd}$  LNT section of the sequential configuration was considerably higher than that over the sandwiched counterpart (0.75L, Figure 1b) despite a similar level of NO<sub>x</sub> converted in both cases. These results support the idea that NO<sub>x</sub> reduction by NH<sub>3</sub> is a major contributor to the N<sub>2</sub>O formation over LNT catalysts [3]. It is thus reasonable to conjecture that N<sub>2</sub>O formation can be further mitigated by increasing the number of alternating LNT-SCR zones due to effective "elimination" of NH<sub>3</sub> entering downstream LNT sections. It has been reported that LNT-generated N<sub>2</sub>O can be reduced over the SCR catalysts by H<sub>2</sub> and NH<sub>3</sub> [1]. However, the involvement of such N<sub>2</sub>O reduction pathways seems to have been minor under our experimental conditions; N<sub>2</sub>O profiles indicate a temporal mismatch between N<sub>2</sub>O and reductant pulses traveling the SCR catalysts (results not shown) as a possible reason.



**Figure 1**: Axial evolution of cycle-averaged NO<sub>x</sub> conversion and N<sub>2</sub>O yield over coupled LNT-SCR catalysts during 60/5-s lean/rich cycling: (a) 1.5" LNT + 1.5" SCR ("sequential" configuration), (b) 0.75" LNT + 0.75" SCR + 0.75" LNT + 0.75" SCR ("sandwiched" configuration); solid line – NO<sub>x</sub> conversion, dashed line – N<sub>2</sub>O yield.

#### Significance

Insights into the interplay between LNT and SCR components gained through spatiotemporal resolution of reactions can facilitate the development of optimal LNT-SCR designs and operating strategies.

### References

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