Rapid hydrocarbon pulsing on a dual-layer LNT-SCR catalyst for low-temperature NOx reduction

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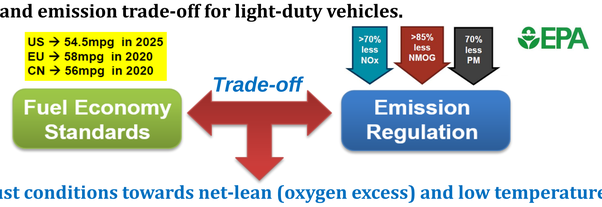
Motivation

❖ Fuel economy and emission trade-off for light-duty vehicles.

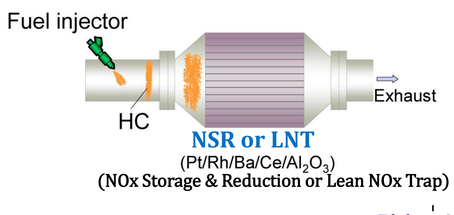


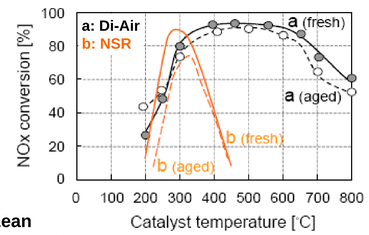
Exhaust conditions towards net-lean (oxygen excess) and low temperatures

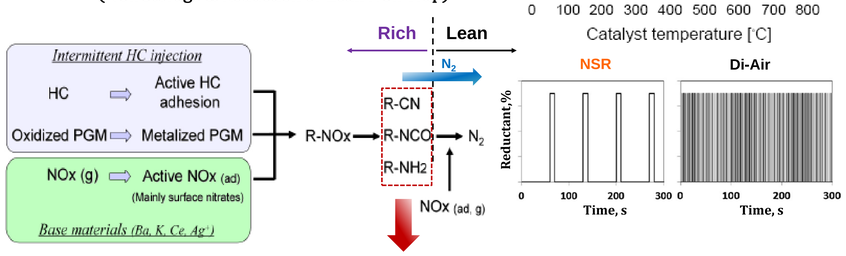
❖ Low-T lean NOx reduction: an key enabler of clean and fuel-efficient passenger cars

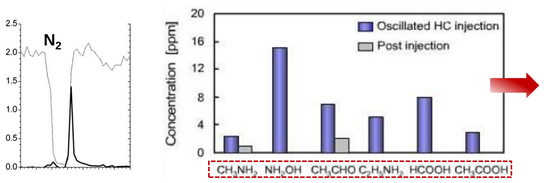
Di-Air System for lean NOx reduction

Toyota's Di-Air system based on
(Diesel NOx aftertreatment by Adsorbed intermediate reductants)









Gaseous intermediates species in LNT outlet

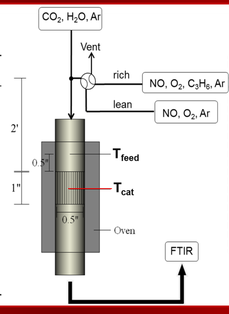
Our conjecture
Addition of Cu-CHA SCR catalyst under rapid HC injection may capture and utilize such by-products via HC-SCR pathway for incremental NOx conversion

SCR: Selective Catalytic Reduction

Effects of cycling frequency and SCR addition

Cycling test (GHSV=80,000h^{-1})

Gas	Lean	Rich
NO	300 ppm	300 ppm
C_3H_6	—	1.8%
O_2	10%	5%
CO_2	5%	5%
H_2O	3.5%	3.5%
$\lambda = \frac{AFR}{AFR_{stoich}}$	$\lambda_{avg.}$=1.81	$\lambda_{rich.}$=0.89



Rich cycle duty (rich period/cycle time) is fixed at 14.3%, 60/10s, 30/5s, 6/1s
Slow NSR — Fast cycling

LNT: (Pt/Rh/Ce/Ba/Al_2O_3) 4.6 g/in^3, BASF
SCR: (Cu-CHA) 1.2 g/in^3, UH

All Catalysts were aged at 700 °C for 33h in air

References

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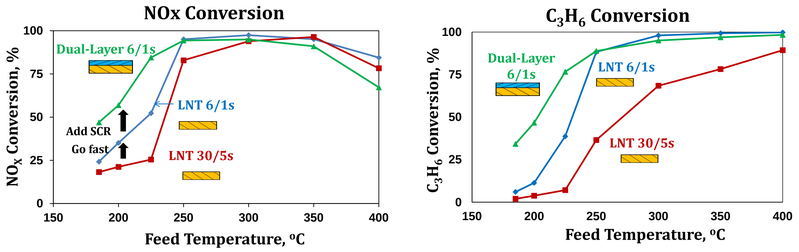
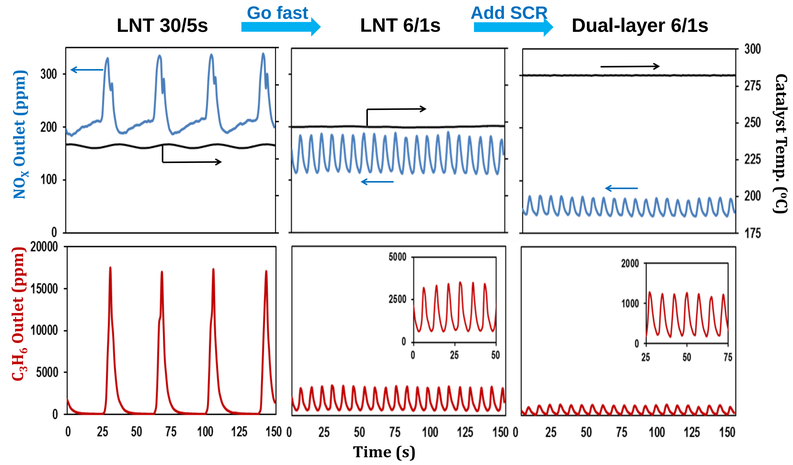


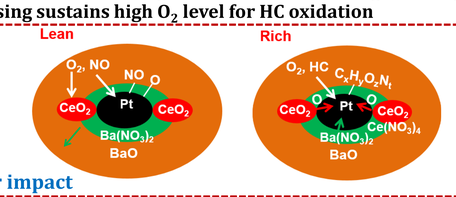
➢ Combination of rapid HC pulsing and SCR layer addition greatly enhance low-T NOx and C_3H_6 conversion

Transient behavior at a feed T of 225 °C



Fast HC pulsing impact

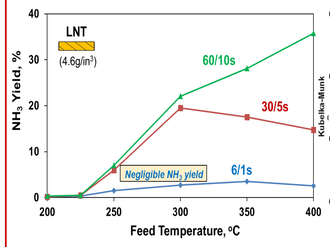
➢ Fast cycling confines NOx storage to surface barium neighbouring Pt
➢ Short HC pulsing sustains high O_2 level for HC oxidation



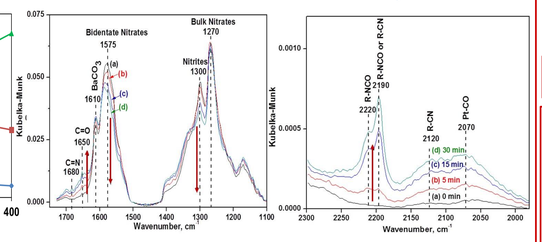
SCR top-layer impact

➢ LNT assisted HC-SCR pathway
➢ Diffusional barrier
➢ Likely thermal effect due to increased thermal mass and reduced heat loss

Cycle frequency impact on NH_3 yield



Surface intermediates identified by DRIFTS



Acknowledgements

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Catalyst: BASF
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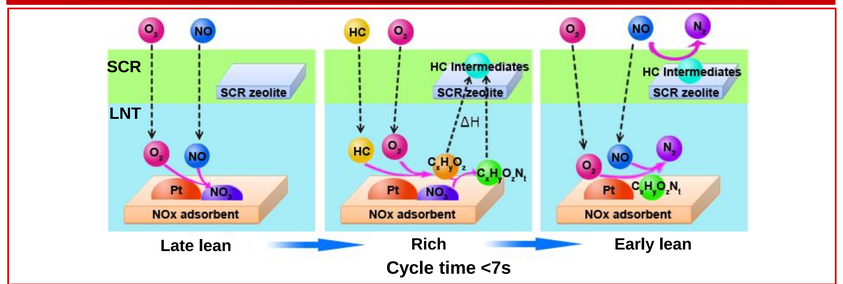
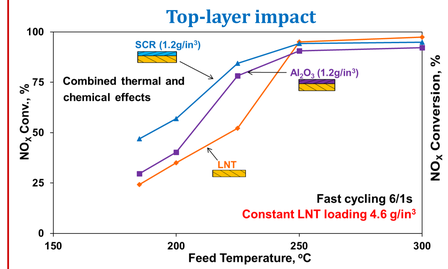
Dr. Bill Epling
Dr. Di Wang

Working principle of fast HC pulsing on dual-layer catalysts

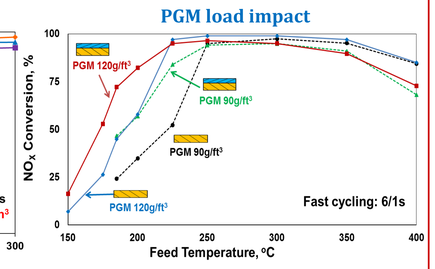


Impact of catalyst design

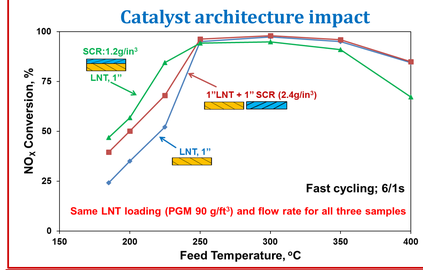
Top-layer impact



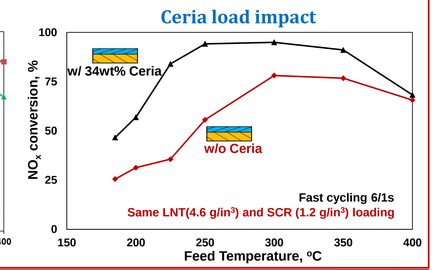
PGM load impact



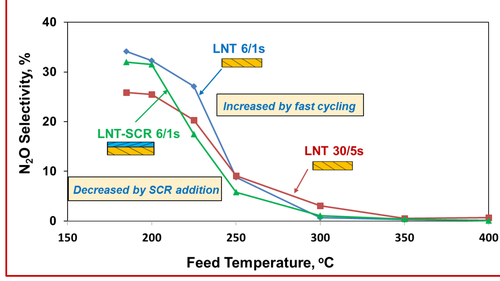
Catalyst architecture impact



Ceria load impact



Cycle frequency and SCR addition impact on N_2O selectivity



Increased selectivity by fast cycling due to higher O_2 level during the HC pulsing;

Decreased selectivity by SCR addition likely due to lower N_2O selectivity for NOx reduction by SCR

Summary and Conclusions

❖ Combination of fast propene pulsing and SCR addition enables high low-T NOx conversion, compared to conventional NSR operation over LNT alone

❖ Under fast cycling partially oxidized HC intermediates instead of NH_3 are the primary NOx reductants for SCR.

❖ Layered catalyst of half reactor volume out-performs sequential one in terms of low-T NOx conversion.

❖ Potential for future improvements
HC-SCR catalysts (Ag-based), PGM zoning, reduced BaO loading;
Different HC species (heavy HC, light/heavy HC mixture), optimal cycling frequency,;