Passive Ammonia SCR
For Lean Burn SIDI Engines

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Outline

- Background and Concept
- NEDC Test Results
  - NH₃ Formation
  - NOx Conversions
- Issues and Summary
Lean NOx Aftertreatment

Lean NOx Trap (NOx Absorber Catalyst)

- High PGM Cost
- Narrow Operating Temperature Window
- Sulfur Poisoning and Desulfation

Urea SCR

- Secondary urea tank with injection system
- High urea consumption
- Urea solution freezing
- Need customer intervention
New Concept: Passive NH₃ SCR

- Use rich pulses to generate NH₃ on the TWC and store it on the SCR
  Rich: \[ NO_x + CO/H_2 \rightarrow NH_3 \]
- Use the stored NH₃ for subsequent lean NOₓ conversion
  Lean: \[ NO_x + NH_3 \rightarrow N_2 \]
- Rich AFR NOₓ must at least balance Lean AFR NOₓ

No PGM required
Goal of the Work

- **Proof of Concept**
  - Ability to make NH$_3$
  - Ability to store NH$_3$ and convert NO$_x$
- **Catalyst Durability**
  - High temperature redox aging
- **Aftertreatment System Architecture**
  - Thermal management

**Experimental**

- **Engine**
  - 2.2L stratified-charge direct-injection engine
  - Controller: d-SPACE with micro-Autobox
- Transient Dynamometer : simulated NEDC cycle
NH₃ Formation over TWC

- NO + 1.5H₂ + CO ⇌ NH₃ + CO₂

CO/H₂ limited ↔ NOx limited

**Graph:**
- ppm NOₓ, ppm NH₃ vs. Engine Air/Fuel Ratio
- ppm H₂ vs. Engine Air/Fuel Ratio

**Legend:**
- NH₃ TWC Out
- NOₓ Eng. Out
- H₂ Eng. Out

DEER Conference 2009
Maximize Lean Operations During NEDC

Lean Operations

Stoich / rich Operations
Rich operations (AFR = 14-14.2) during accelerations lead to NH$_3$ formation; minimum FE penalty (within test variability) based on test cell data.
Passive SCR conversion window about as broad as LNT, but at lower temperatures
- Lacking steady NH₃ supply, passive SCR NOₓ conversion limited at high temperature
- Effective NOₓ conversion only possible in reduced window of operation
NH$_3$ Storage Capacity Limitations
– Why passive SCR has smaller conversion window

- Passive SCR is a discontinuous approach – must store NH$_3$ for use in lean periods
- Storage capacity of known catalysts is negligible beyond 400 C
- Effective NO$_X$ conversion limited by intrinsic storage capacity
Operating temperature window can be expanded with a multiple-SCR architecture.
NO$_x$ Conversion Efficiencies over SCR

[Graph showing NO$_x$ Concentration over Test Time and Vehicle Speed (km) and Temperature (°C)]

- TWC Out NO$_x$
- SCR Out NO$_x$

Passive SCR Conversion Window

SCR1 Bed T
Multiple-SCR architecture required to reduce NOx emissions during high speed (>100km/h) lean cruise during EUDC
NEDC Test Results with NH₃ SCR

- Passive NH₃ SCR has potential to meet Euro6 emission targets with aged converters
- Minimum fuel economy penalty for NH₃ formation during NEDC (within test variability)
- No significant slip of secondary emissions (NH₃, N₂O)

**Remaining Issues**

- NH₃ formation and OBD control method
- Sulfur impact: sulfur is known to greatly inhibit NH₃ formation on TWC
- HC emission reduction is challenging due to the low exhaust temperatures
- Further improvements in SCR catalyst technologies are required for high speed (≥100 km/h) lean operations.
Summary

- Passive NH$_3$ SCR has been demonstrated as a high efficiency and low cost alternative lean NO$_x$ aftertreatment technology for stratified gasoline engines.
- Very high NO$_x$ conversion efficiencies were achieved during NEDC transient cycles.
- Multiple SCR architecture expands the operating temperature window of passive SCR.
- Plan to further develop the system for US applications (SULEV)

Passive NH$_3$ SCR: key enabler for lean gasoline engines