Advanced Diesel Oxidation Catalyst Technology for Passenger Cars

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Contents

- What are diesel exhaust gas emissions
- What are diesel oxidation catalysts
- How do they function
- Why are they still needed
- Conclusion

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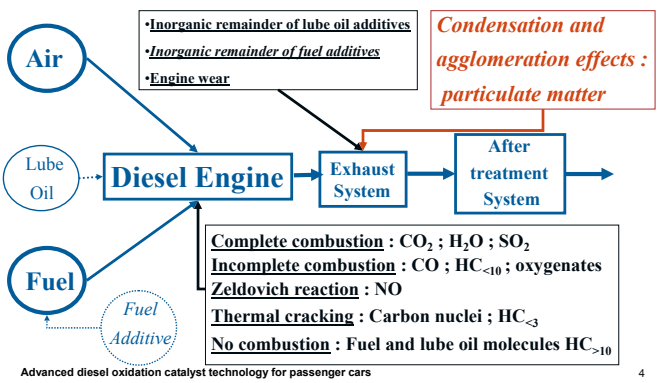
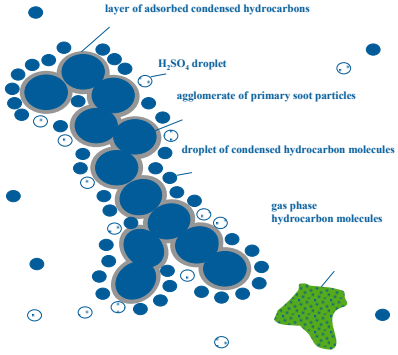
What are diesel exhaust gas emissions

Origin of exhaust emissions



What are diesel exhaust gas emissions

Structure of Particulate Matter



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- How do they function
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What are diesel oxidation catalysts

Summary

- **Passive exhaust aftertreatment devices**
  - → no interaction with EMS needed
- **PGM containing catalysts**
  - → PGM - content 2 - 180 g / ft³
  - → today mainly Pt - only formulation
  - → historically also Pd and Pt / Pd-used
- **Applied on flow through monoliths**
  - → mainly ceramic 300 cpsi / 8 mill & 400 cpsi / 6.5 mill
  - → more recently also on advanced metallic substrates
- **Used on PC since 1989 and HDT since 1993**
- **Various technology generations exist**

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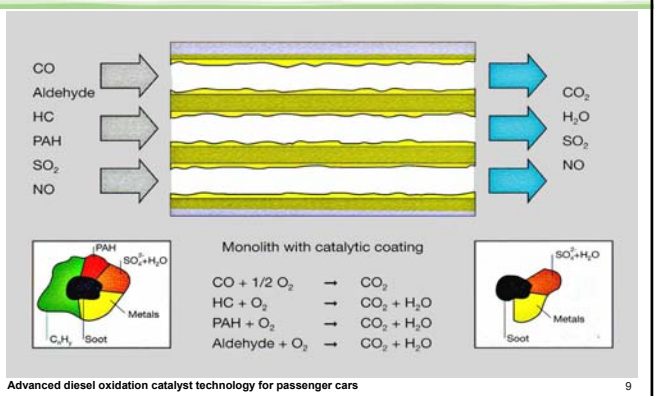
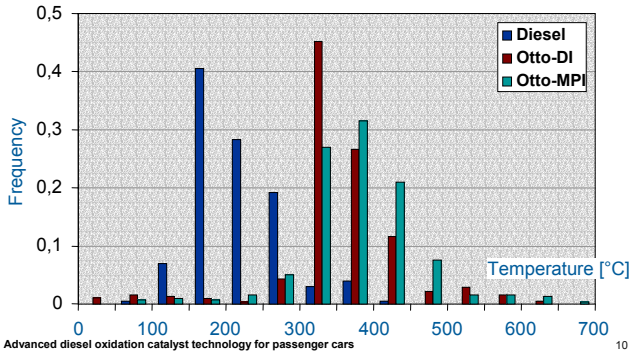
How do they function

Working principle of the Diesel Oxidation Catalyst



How do they function

Comparing exhaust gas temperatures in NEDC



How do they function

Key design and operation features

- **Selective catalysis of oxidation reactions**
  - → excellent conversion of CO, HC $_{2-4}$ & HC $_{10-24}$
  - → good conversion of $C_xH_yO_z$
  - → preferably no conversion of SO_2
  - → conversion of NO only in special applications
- **Catalysis at low temperatures**
  - → good light off needed
  - → avoid deposition of PM, SO_x & HC $_{10-24}$
  - → still good thermal stability needed
- **Able to handle three phase flow**

How do they function

Possible mechanical deactivation phenomena

Diesel oxidation catalyst - inlet side - after 90 Tkm road ageing

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How do they function
Possible chemical deactivation phenomena

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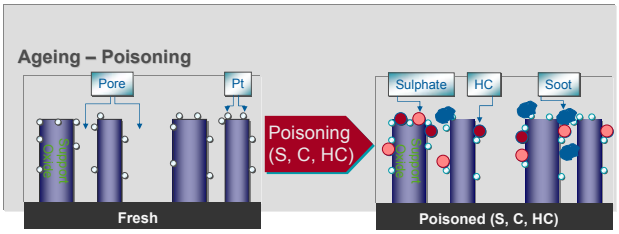
Conventional Diesel Oxidation Catalysts



→ S/C/HC deposits on the platinum and in the pores
→ Potential clogging of pores, decrease of accessible specific surface area
→ Precious metal might not be completely available for catalytic reactions
→ Poisoning is only partially reversible

How do they function
Possible thermal deactivation phenomena

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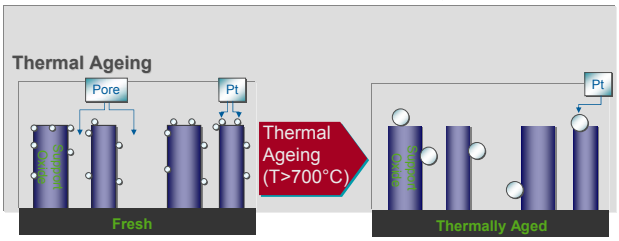
Conventional Diesel Oxidation Catalysts



→ Sintering of highly dispersed platinum particles
→ Decrease of catalytically active surface area of platinum
→ Thermal ageing is irreversible

How do they function
Operation conditions & legislation : generation 1

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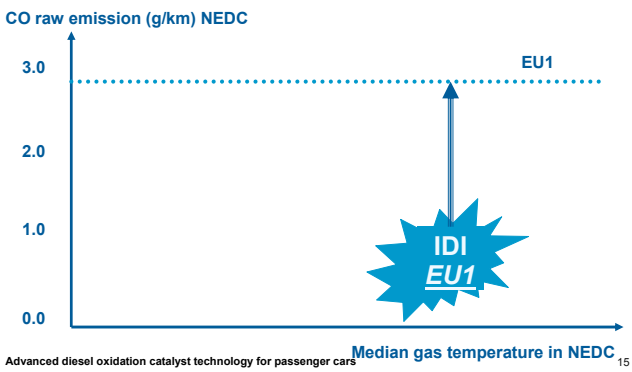

How do they function
Performance & boundary conditions : generation 1

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EU 1

DOC Gen. 1

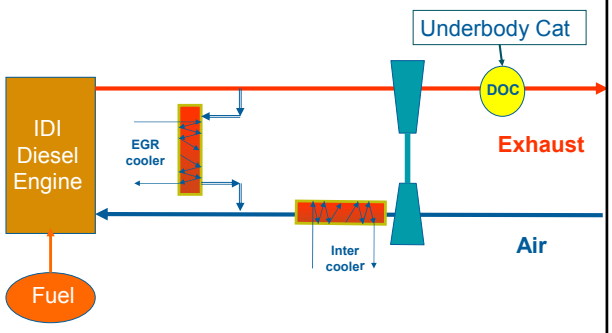
- high PM mass reduction
- high SOF removal
- no SO_4 formation
- medium CO /HC removal
- high odor reduction

IDI Engine

High Sulfur Fuel

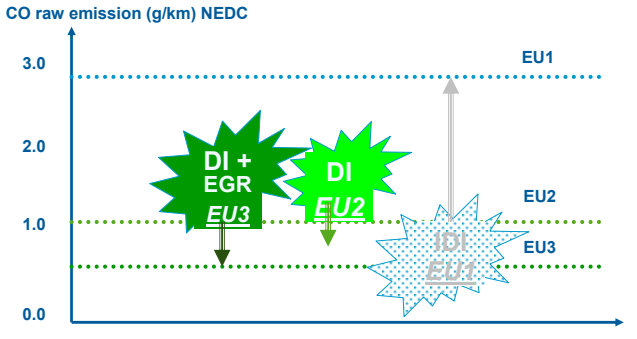
How do they function

Exhaust system architecture : generation 1



How do they function

Operation conditions & legislation : generations 2 & 3



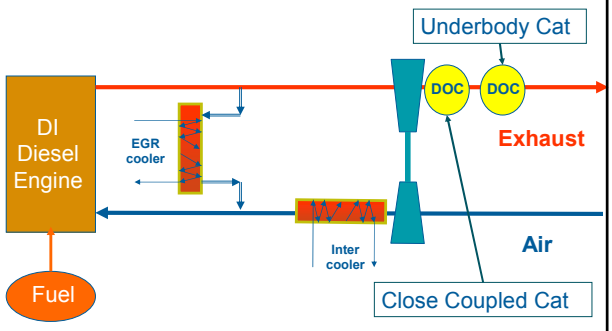
How do they function

Performance & boundary conditions : generations 2 & 3

EU 1	EU 2&3
DOC Gen. 1	DOC Gen. 2&3
• high PM mass reduction • high SOF removal • no SO_4 formation • medium CO /HC removal • high odor reduction	• high CO removal • medium HC removal • high SOF removal • high odor reduction • (high SO4 formation)
IDI Engine	DI & DI-TC Engine
High Sulfur Fuel	Medium Sulfur Fuel

How do they function

Exhaust system architecture : generations 2 & 3



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How do they function

Operation conditions & legislation : generation 4

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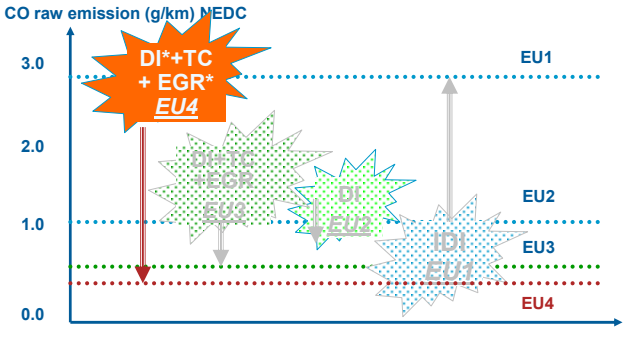

How do they function

Performance & boundary conditions : generation 4

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EU 1	EU 2&3	EU 4
DOC Gen. 1	DOC Gen. 2&3	DOC Gen. 4
• high PM mass reduction	• high CO removal	• *heating function*
• high SOF removal	• medium HC removal	• very high CO removal
• no SO_4 formation	• high SOF removal	• high HC removal
• medium CO /HC removal	• high odor reduction	• (high SOF removal)
• high odor reduction	• (high SO4 formation)	• high odor reduction
		• (high SO4 formation)
IDI Engine	DI & DI-TC Engine	DI**-TC Engine
High Sulfur Fuel	Medium Sulfur Fuel	Low Sulfur Fuel

How do they function

Exhaust system architecture : generation 4

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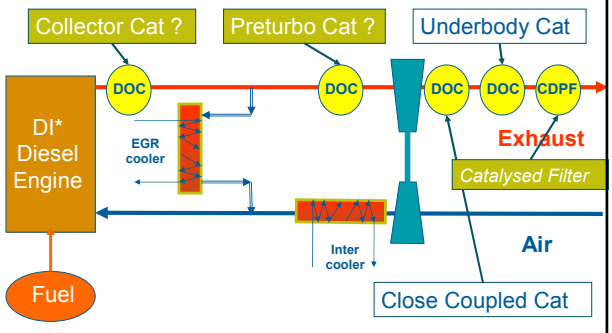

How do they function

Effect of preturbo catalysts on CO emissions in NEDC

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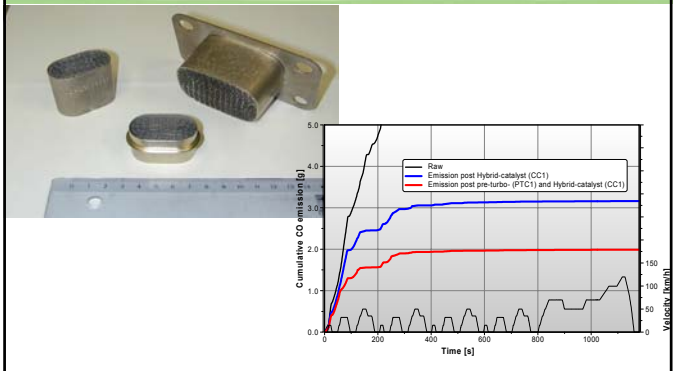

Source : Emitec & Umicore publication Dresdener Motorensymposium 2004

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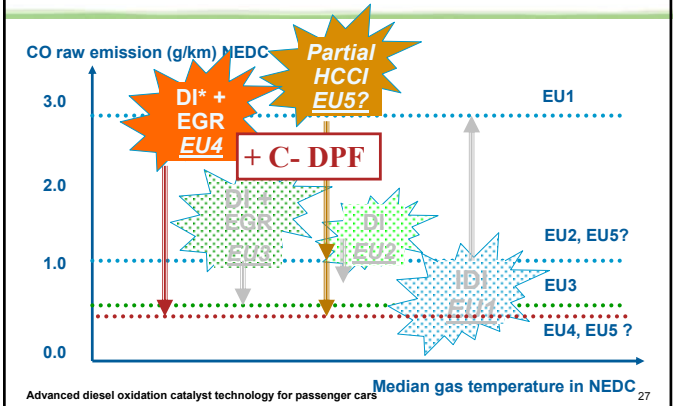
Why are they still needed
Overview

Fifth generation passive DOC

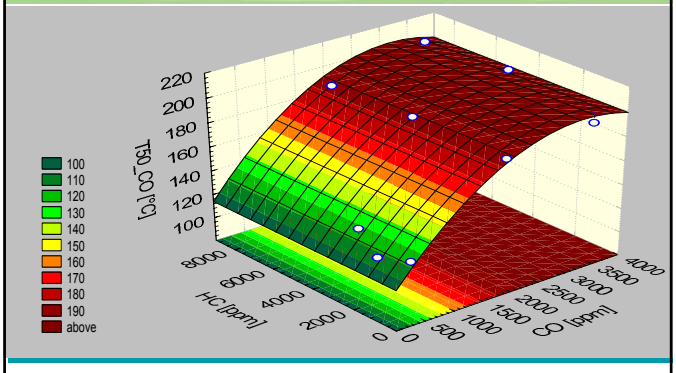
- excellent CO & HC performance
- very high CO & HC raw emission
- ultra-low sulfur fuel

Future of advanced oxidation catalysts

Why are they still needed
Operation conditions & legislation : generation 5



Why are they still needed
CO light-off for HCCI-Applications - model gas testing



Why are they still needed
Overview

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Fifth generation passive DOC
- excellent CO & HC performance
- very high CO & HC raw emission
- ultra-low sulfur fuel

Future of advanced oxidation catalysts

EGR DOC
- pre-EGR-cooler
- oxidise HC $_{10\text{-}23}$
- prevent fouling

Why are they still needed
New applications - EGR cooler protection catalyst

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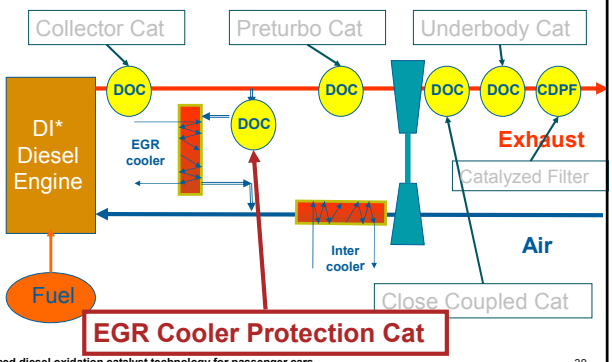

Why are they still needed
EGR cooler protection catalyst - Toyota IAA 2003

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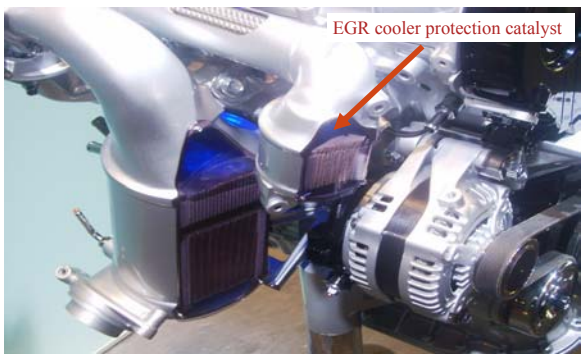

Why are they still needed
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Future of advanced oxidation catalysts

EGR DOC
- pre-EGR-cooler
- oxidise HC $_{10\text{-}23}$
- prevent fouling

Active DOC
- pre-DPF
- heating DPF
- NO2 generation

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Why are they still needed

Catalytic combustion for enabling the DPF regeneration

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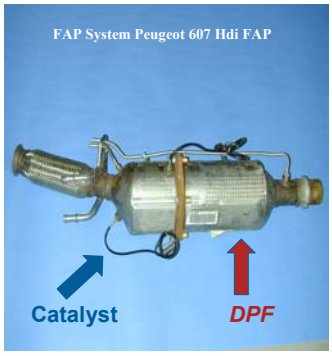

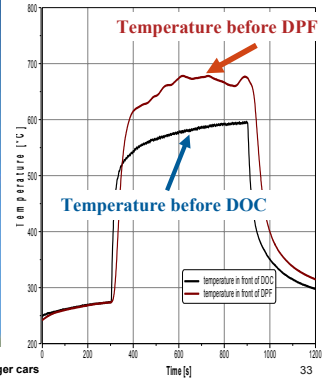

Why are they still needed

CO & HC & PM emissions after a DOC + DPF system

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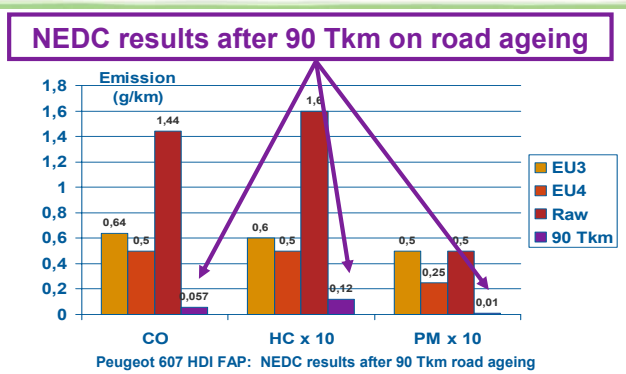

Peugeot 607 HDI FAP: NEDC results after 90 Tkm road ageing

Why are they still needed

Active DOC + DPF system enables Pt/Pd use in DOC

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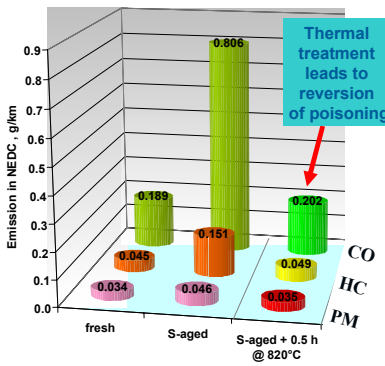

Thermal treatment leads to reversion of poisoning

Vehicle Test :
- 3.0 L CR-TDI engine
- 2 x 1.09 L catal. Volume
- pre catalyst only
- NEDC testing

Catalyst states
- fresh state
- low temp. sulfur aged with 2400 ppm S-fuel)

Catalyst
- Advanced Pt / Pd DOC
- total PGM loading : 70 g/ft³

Why are they still needed

Cost reduction of DOC + DPF by use of Pt/Pd in DOC

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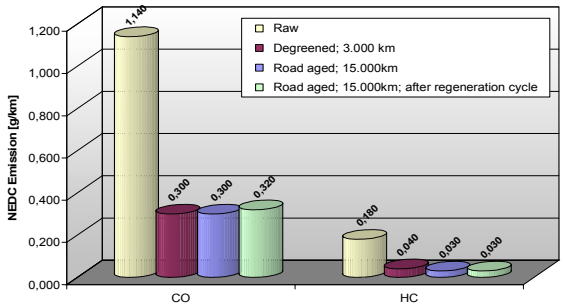
Catalyst size: dia 5.66" x L :3.5"; **PGM loading**: 120 g/ft³ ; **Vehicle** : 2.2l CR TDI



Why are they still needed
Overview

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Fifth generation passive DOC
- excellent CO & HC performance
- very high CO & HC raw emission
- ultra-low sulfur fuel

Future of advanced oxidation catalysts

EGR DOC
- pre-EGR-cooler
- oxidise HC $_{10\text{-}23}$
- prevent fouling

Active DOC
- pre-DPF
- heating DPF
- NO2 generation

C-DPF
- high CO & HC conversion
- local DPF heating
- multiple NO/NO2 cycle

Why are they still needed
Integration of DOC in Particulate Trapping Substrate

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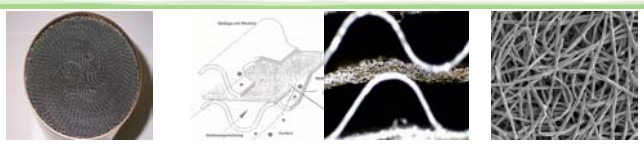

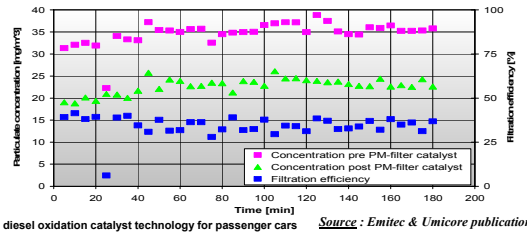

Source : Emitec & Umicore publication Dresdener Motorensymposium 2004

Why are they still needed
Overview

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Fifth generation passive DOC
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SCR system catalysts
- NO2 generation
- NH3 conversion
- CO & HC conversion

Future of advanced oxidation catalysts

EGR DOC
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Active DOC
- pre-DPF
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C-DPF
- high CO & HC conversion
- local DPF heating
- multiple NO/NO2 cycle

Why are they still needed
Dedicated Diesel oxidation catalyst use in SCR systems

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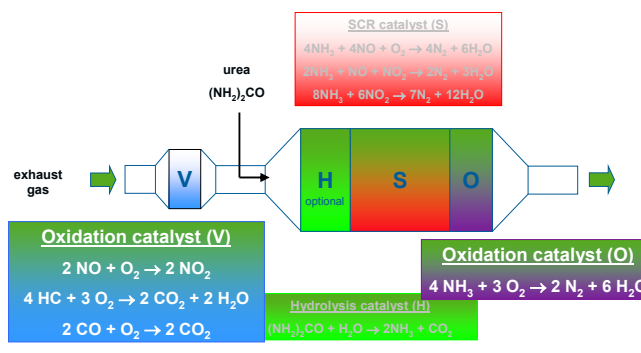

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Conclusion

- DOC are a proven technology
- technical potential still not exhausted
- new tasks emerge for the DOC
- DOC become active system components
- DOC will be part of EU5 catalyst systems !

Acknowledgements

I wish to thank hereby my highly dedicated and motivated team in Hanau that generates these technologies and the data I presented about them. Special thanks to Gerald Jeske, Frank Schuetze, Stefanie Frantz, Paul Spurk, Mechtild Muller, Kerstin Herrmann, Bernd Loesche , Hans-Juergen Reinwarth, Martin & Markus Eisel and Sabine Leder

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