Catalytic aftertreatment of PM emissions (Katalytisk efterbehandling av partikelemissioner)

Project summary

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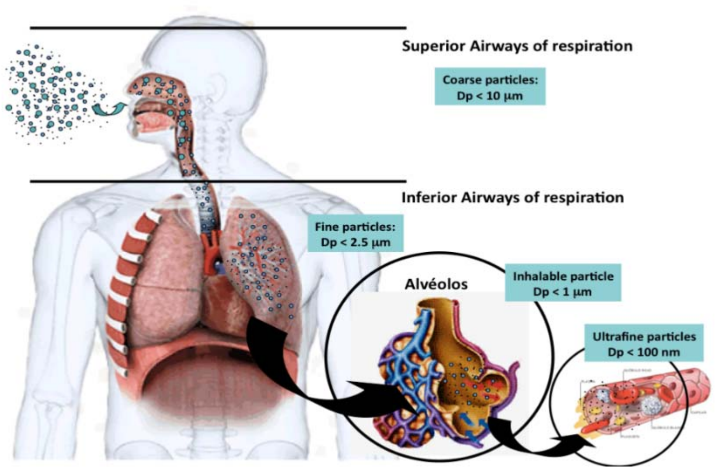
Catalytic aftertreatment of PM emissions

- Start: January 2013, end July 2017
- Main grants receiver: Chalmers
- Industrypartners:
  - Volvo Group,
  - Volvo Cars Corporation
  - Haldor Topsoe AS
- FFI-programme: Energy and Environment
- Grant: 4.01 MSEK
- Final report: http://www.energimyndigheten.se/forskning-och-innovation/projektdatabas/sokresultat/?projectid=17761

Motivation

- > 6 Million deaths due to ambient air pollution [1]
- Road transportation needs lower CO_2 emissions and “zero” local emissions
  - Efficient filters needed (DPF & GPF)
  - With low pressure drop (low fuel penalty)



[1] WHO (2016). Ambient air pollution: A global assessment of exposure and burden of disease.

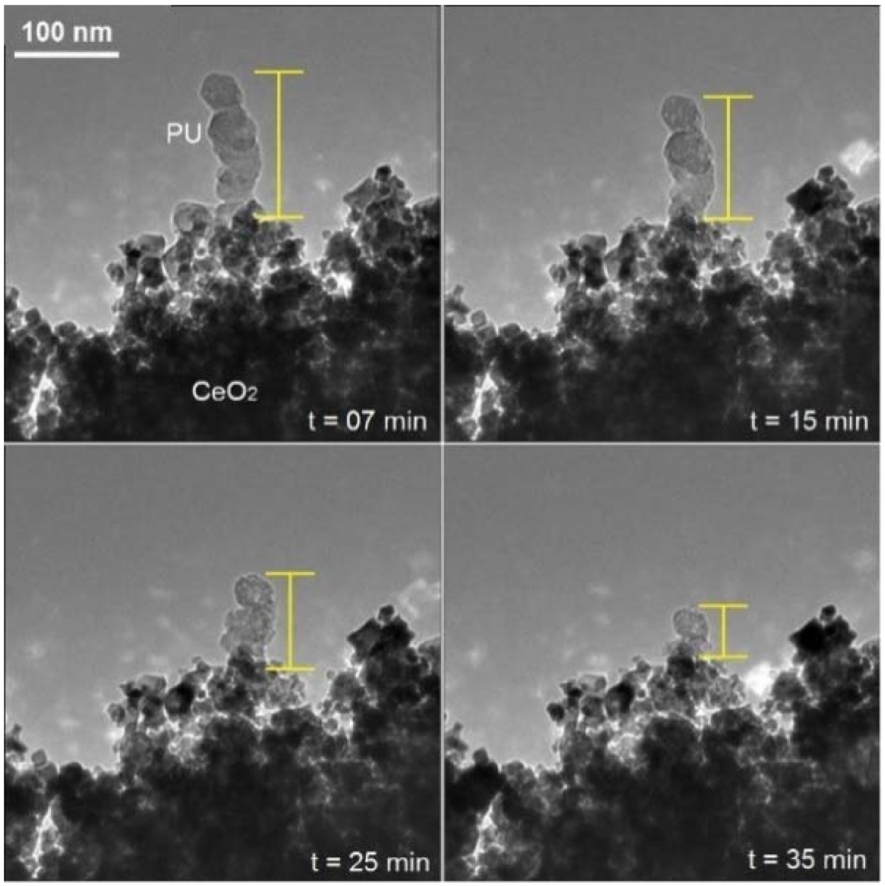
Project objectives

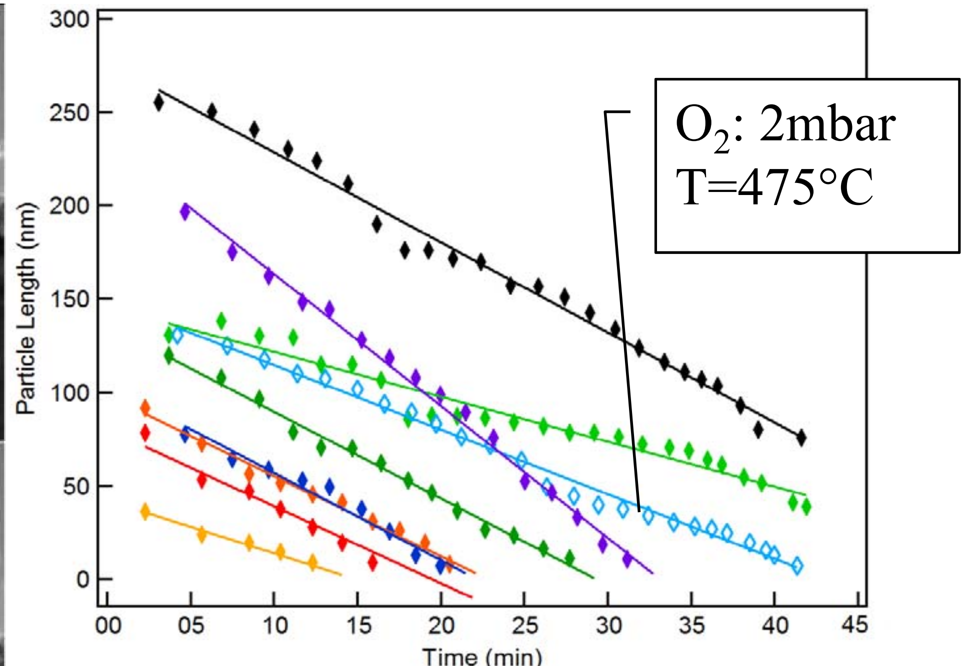
- To increase understanding of soot oxidation
  - To reduce CO_2 emissions
  - To enable oxidation at lower temperatures
  - Effects of upstream EATS component (DOC)
- To bridge the gap between lab scale and full scale experimentation

Project description (Outline)

1. Soot oxidation at Nano-scale
2. Method development at lab scale
3. Soot oxidation of synthetic soot and of collected particulate matter(Light duty diesel)
4. Soot oxidation of collected particulate matter (Heavy Duty Diesel) in mini DPF

Soot oxidation at nano-scale





r ~ exp(-Ea/RT)*O_2^b

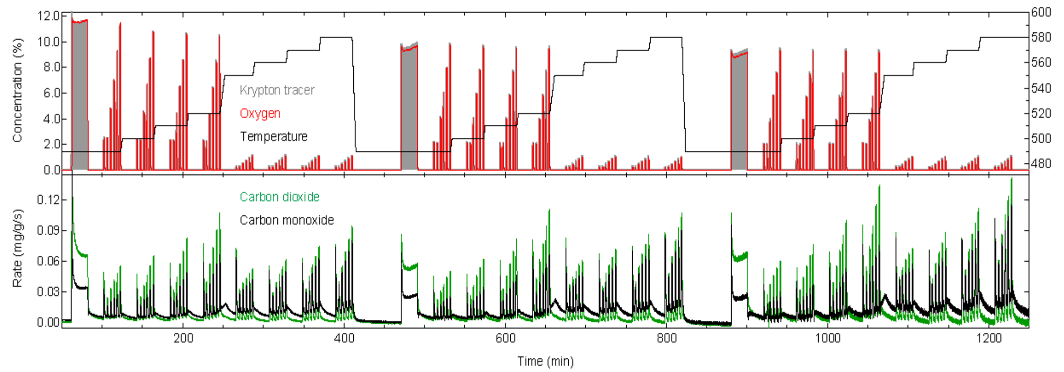
Ea ~ 113kJ/mole

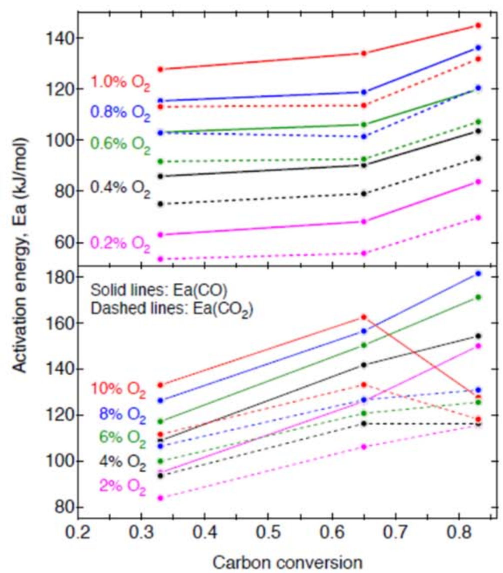
b ~ 0.84

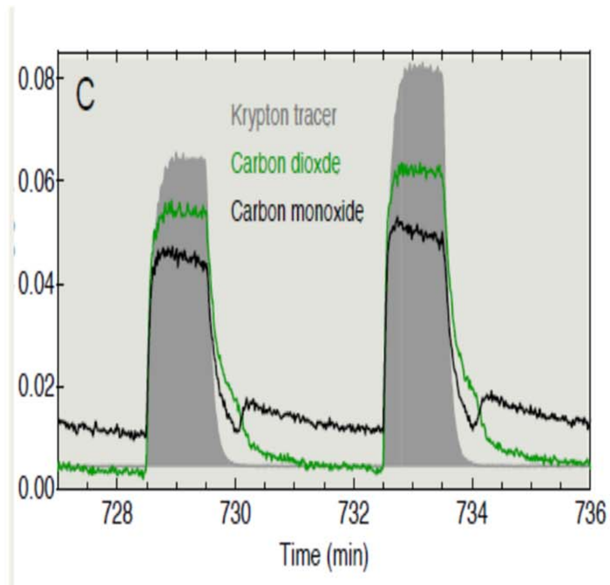
Ian J. Allen et. Al., "**Mechanism and kinetics of oxide-catalyzed soot oxidation studied by electron microscopy**", in manuscript

Method development

- Short pulses
  - Varying O2 conc.
  - Varying Temp.
  - @ 3 conversions
- Results
  - Apparent Ea change with conversion and with O_2 conc.
  - Tracer exp. Indicates significant surface species

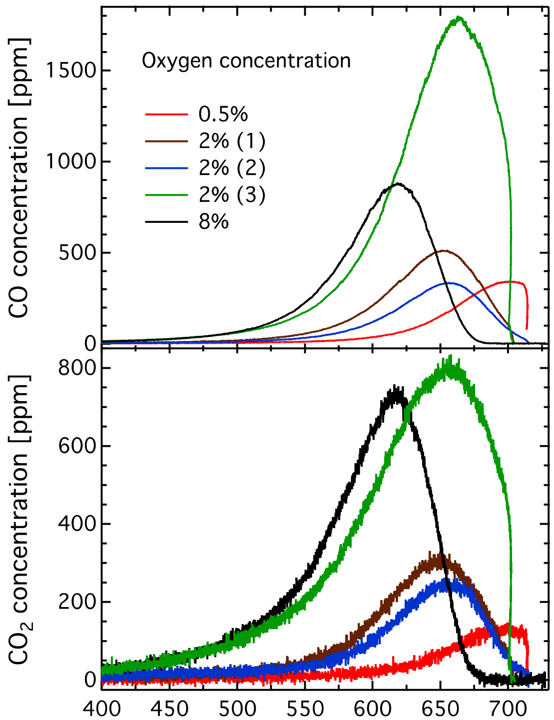


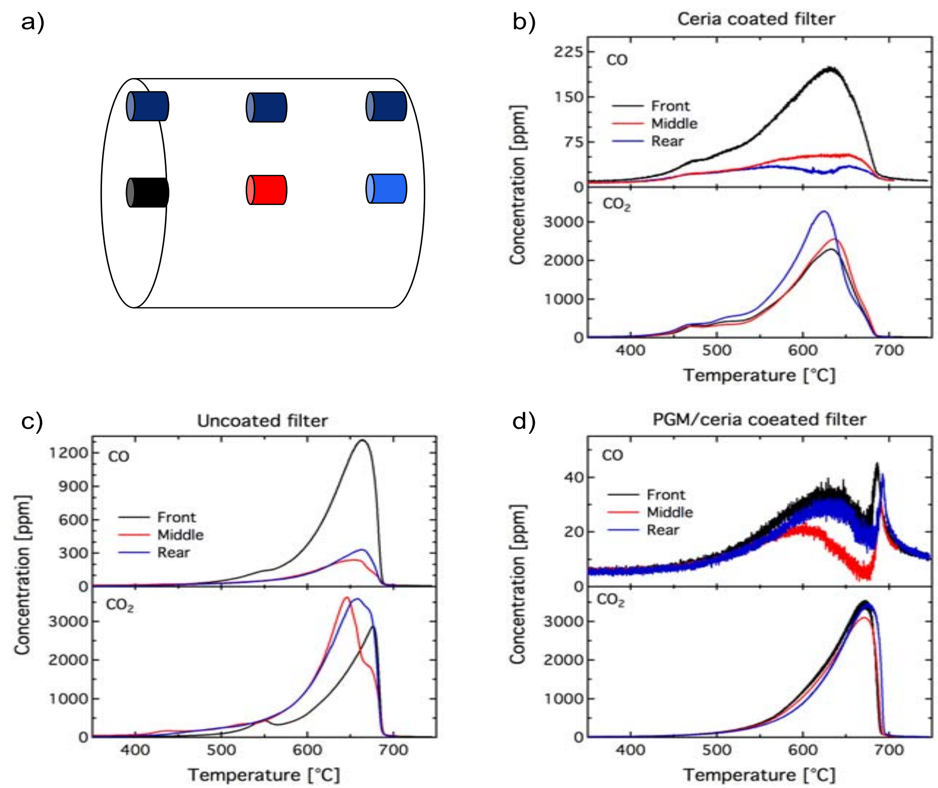




M. Englund et al., “Pulse experiments for investigation of soot oxidation kinetics”, CAPoC 10 Brussels 2015

Comparison lab scale-engine PM

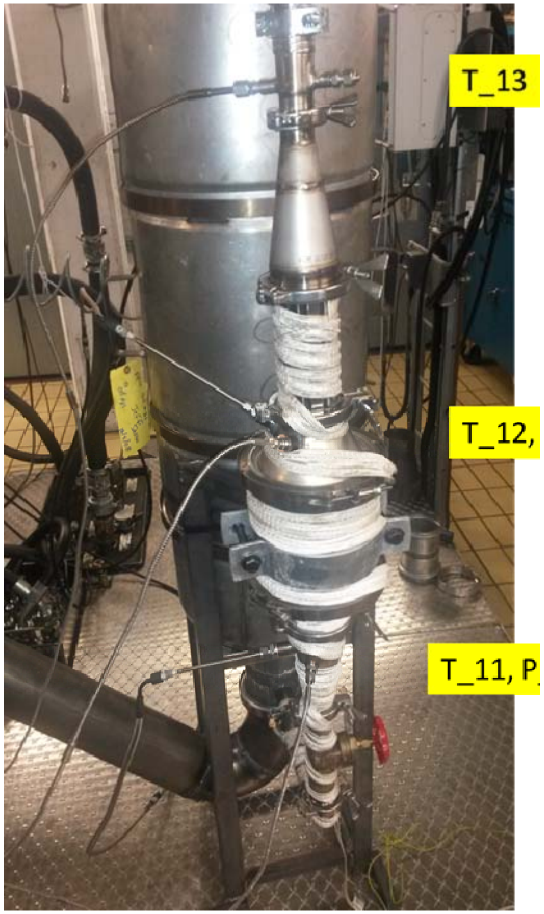




- Apparent on-set depends on O_2 and m_C
- $r_{CO} > r_{CO2}$
- More PM at inlet
- Catalyst lower onset temperature
- $r_{CO} < r_{CO2}$

Soot sampling in mini-DPF

- 24 mini DPFs
  - Different coatings
  - Short & Long loading
  - With & without DOC
- Soot oxidation in lab-scale reactor
  - Pulse experiments
  - O_2 & NO_2 oxidation

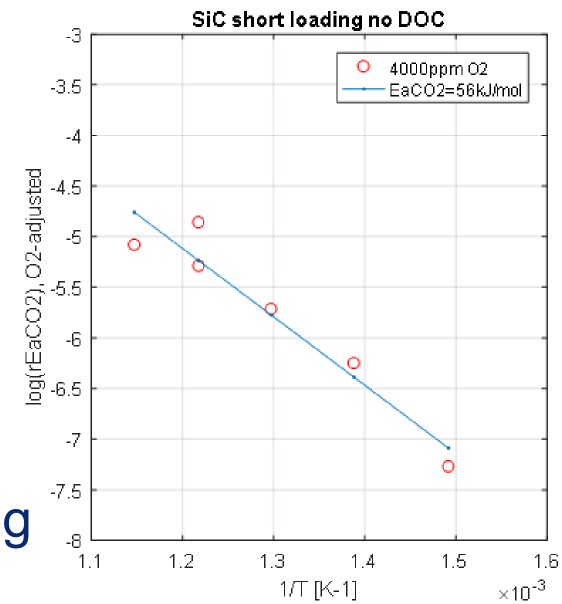


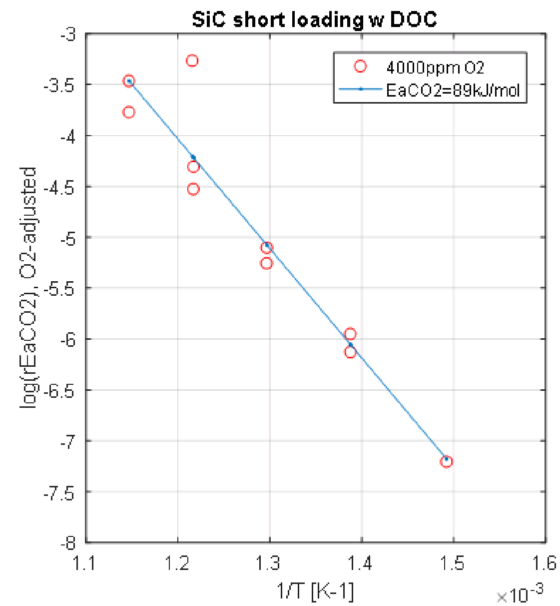
Kinetics analysis

- Global reaction scheme
  - $r = k e^{-Ea/RT} m_0 (1-X)^{2/3} O_2^{0.8}$
- Ea higher w DOC
  - HC "stripped" in DOC

Not shown:

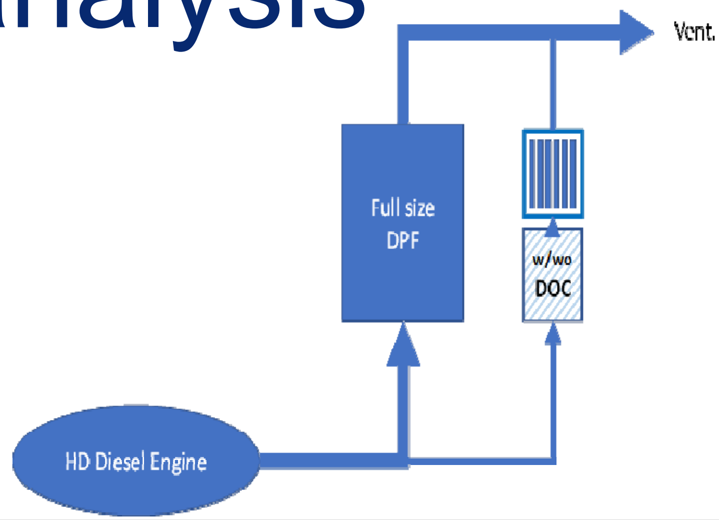
- Ea lower for high PM loading
  - Mas transfer limitations
- $r_{CO} < r_{CO2}$



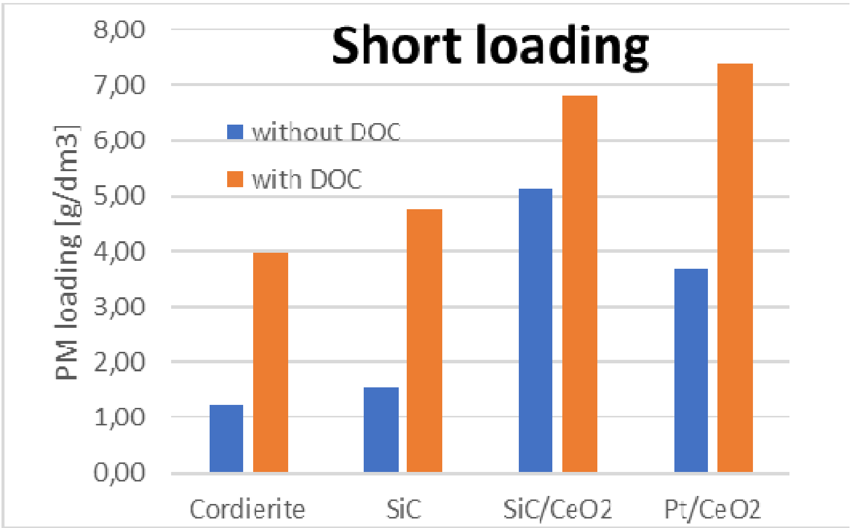


H. Ström, J. Sjöblom et. al." **Near-wall dispersion, deposition and transformation of particles in automotive exhaust gas aftertreatment systems**", submitted to Int J Heat and Fluid Flow

Soot loading analysis



- Higher loading w DOC
  - Same "driving force" (big DPF)
  - Stripped PM in DOC gives "narrow" PSD
    - Lower "specific pressure drop" => higher flow (more PM collected)
- Similar effect from catalyst



Summary

- Increased understanding of soot oxidation
  - Lower pressure drop by use of DOC & catalyst
  - Reaction rate depends on
    - Oxidant and oxidant concentration (incl. adsorbed O)
    - Degree of conversion
    - Particle size (engine operation)
    - Amount of VOC (adsorbed HC)
    - Catalyst
- Bridging the gap from small scale to full scale
  - Oxidation by O2: power of ~0.8 (ETEM & HD-PM)
  - Differences in flow through and DPF reactor

Implications for PM emissions control

- **Adsorbed species** as intermediates needed to model transient behaviour
- Different “aged” PM at all times calls for **population balance** modelling approach
- **Upstream components** and flow field aspects will influence PM capture and resulting pressure drop
- Soot cake internal **mass transfer limitation** should be considered

Acknowledgements

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- Volvo Group: Jan Koegler
- Haldor Topsoe: Keld Johansen, Ian Allen