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Particulate Matter of “Soot-Free” Fuels in a Cylindrical Constant Volume Chamber

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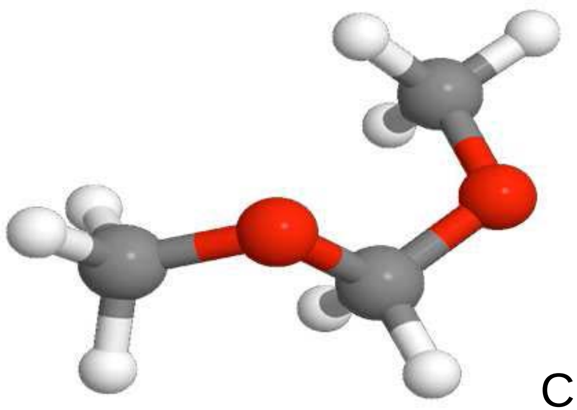
Presentation Outline

- Motivation and Objective of Investigation
- Experimental Set-up and Test Conditions
- Results and Discussion
- Conclusion

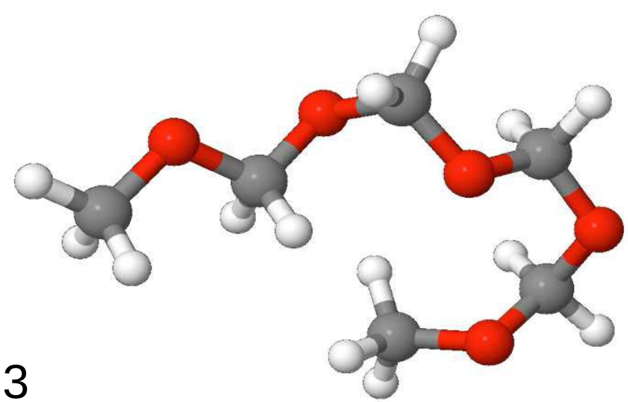
Motivation and Objective of Investigation

- Oxygenated fuels are known to be helpful for reducing nanoparticle emission in internal combustion engines

- The aim of the present study is the understanding of oxygenated fuels (within the POMDME (**OME**) family) contribution on soot formation process reduction within the combustion chamber.



$CH3O(CH2O)_nCH3$



J. Burger, 2012

Investigated Fuels

The activity is focused on the effect of different oxygenated fuels on soot formation process reduction. The investigated fuels are:

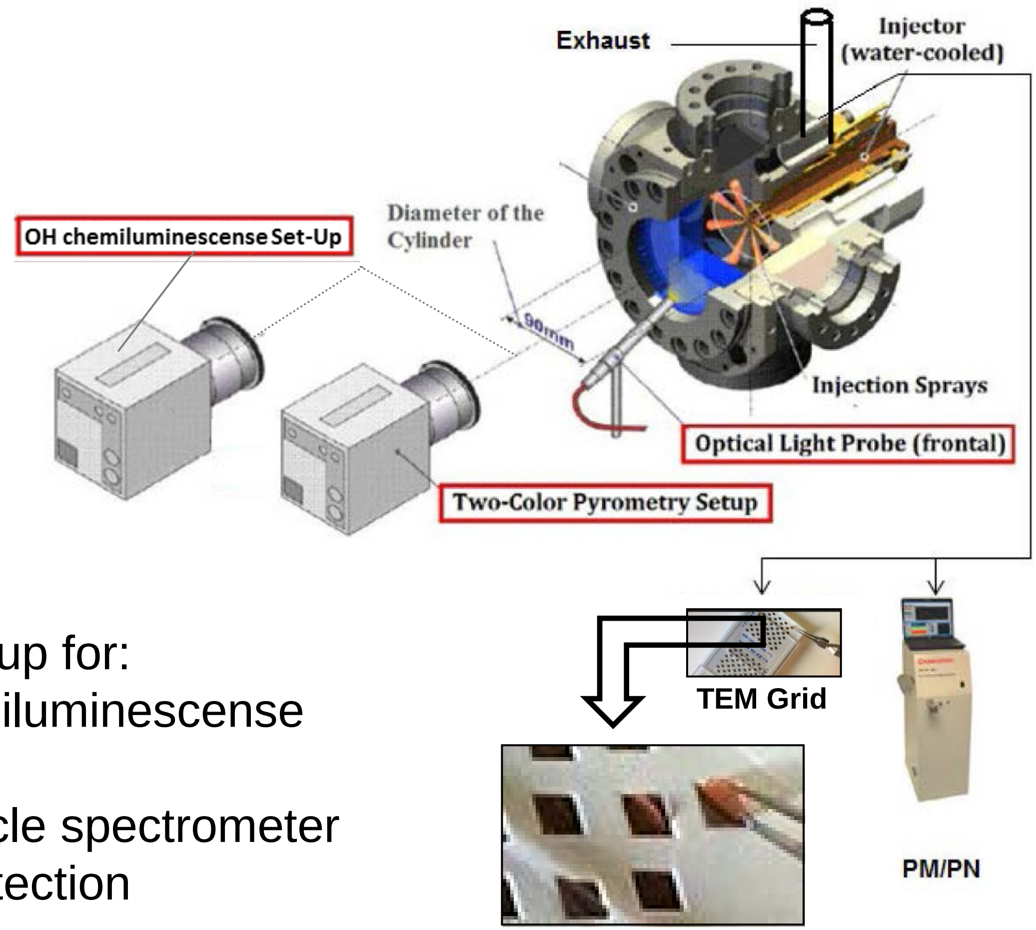
- Commercial diesel
- OME1 (or DMM (dimethoxymethane), POMDME with n=1)
- OME2 (POMDME with n=2) pure and blended in different percentages (50, 30 and 5%) with commercial diesel
- A blend of different POMDMEs with n=2, 3 and 4

	CDF	DMM	POMDME		
			$n=2$	$n=3$	$n=4$
Melting point (°C)	–	−105	−70	−43	−10
Boiling point (°C)	170–390	42	105	156	201
Viscosity (25 °C) (mPa s)	2.71	0.58	0.64	1.05	1.75
Density liquid (25 °C) (kg/L)	0.83	0.860	0.960	1.024	1.067
Cetane number	55	29	63	70	90
Oxygen content (wt%)	–	42.1	45.3	47.1	48.2

J. Burger et al, 2010

Experimental Set-Up

- The experiments are carried on a cylindrical constant volume chamber in which a temperature up to 720K can be set.
- Optical access from the front window.

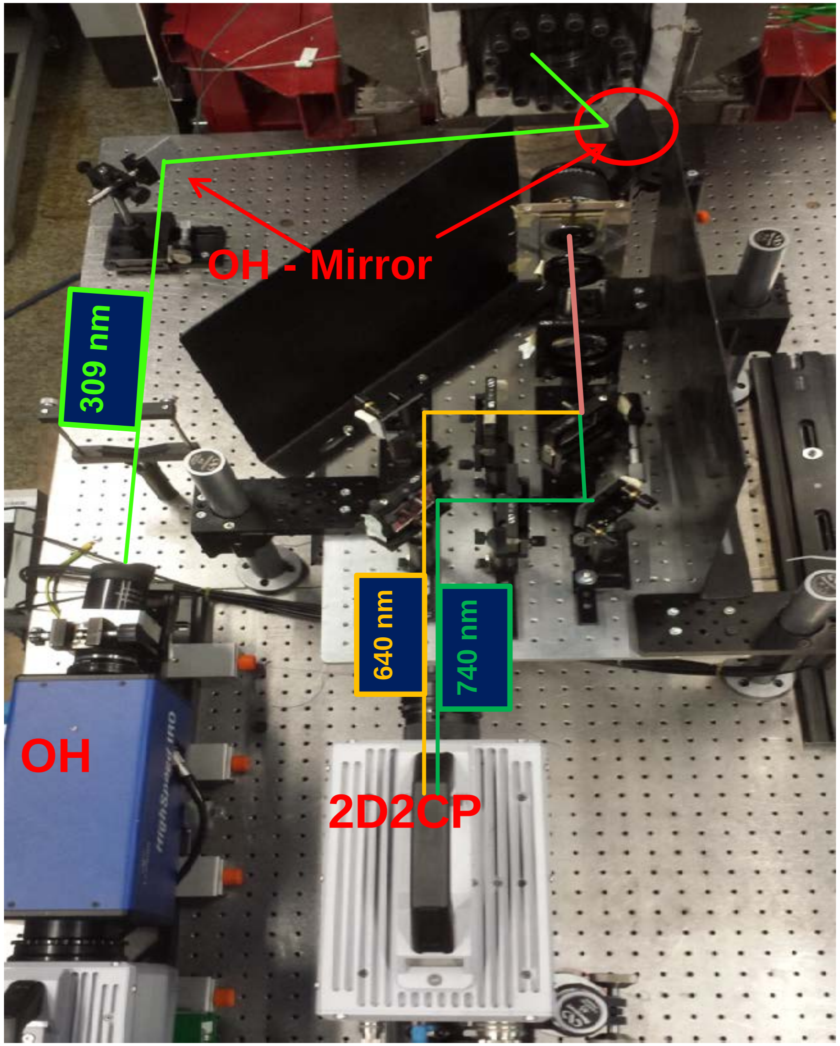


- 2 cycle resolved cameras + set-up for:
  - OH chemiluminescense
  - 2D2CP
- Cambustion DMS 500 fast particle spectrometer
- A TEM grid for nanoparticles detection

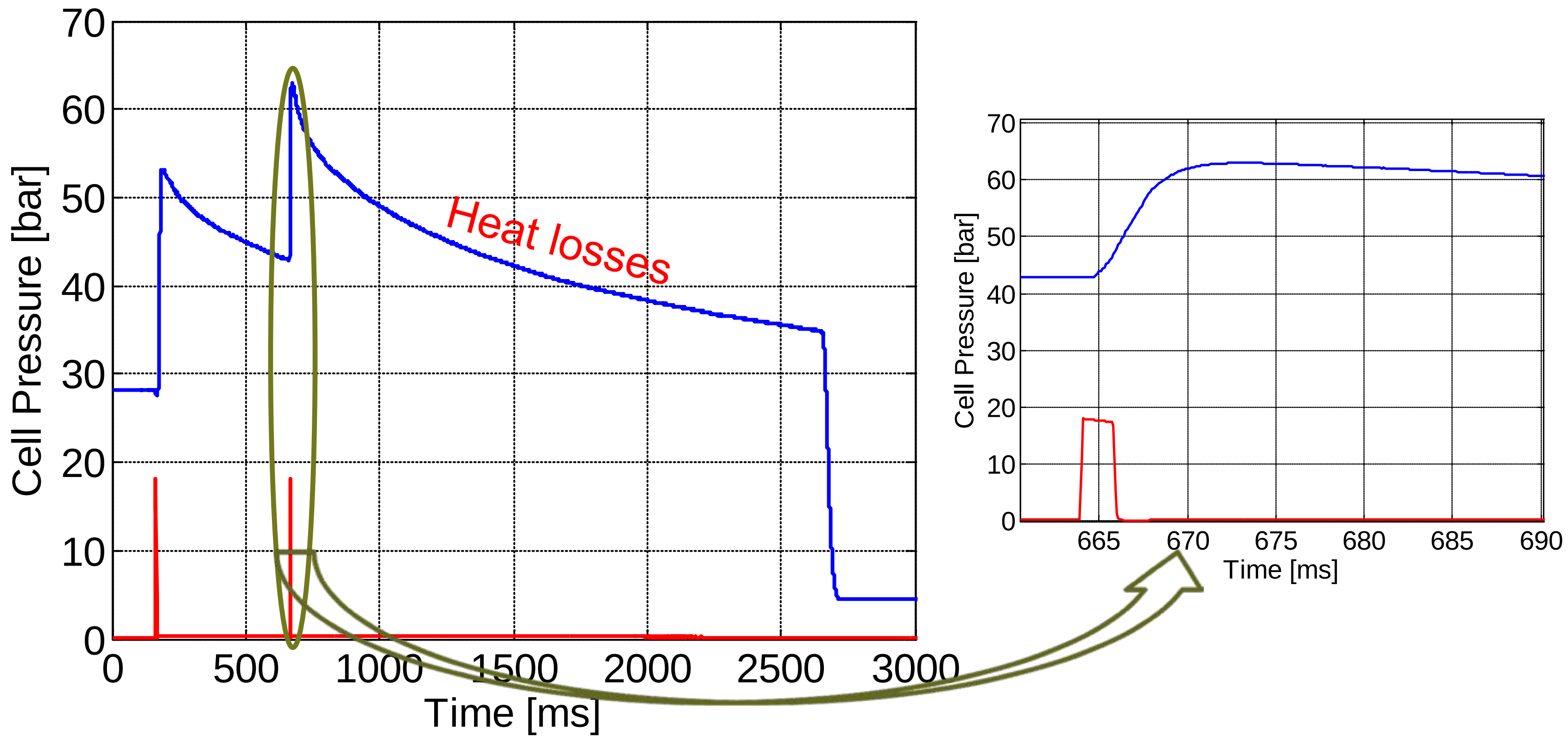
Optical results

The experimental apparatus includes two optical set-up:

- 2D2CP
- OH chemiluminescense



Operating conditions



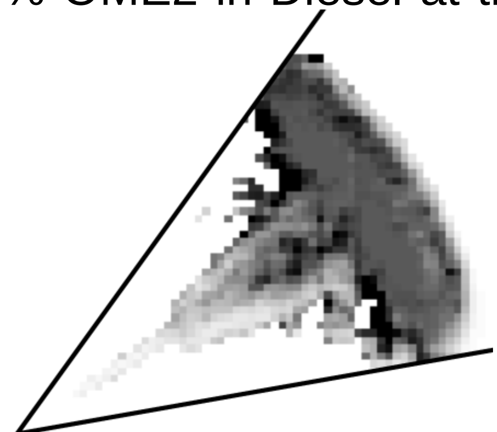
- Cell Temperature before SOI: 713 K
- 1st injection just used to pre-heat the cell
- Dwell time between 1st and 2nd injection managment determines different temp. at start of 2nd injection
- *In cell pressure decrease due to heat losses*.

Ignition delay and premixed combustion variation

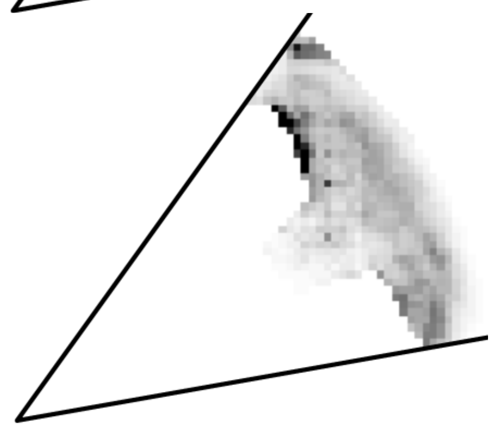
Optical results, 2D-2-Colour Pyrometry

2D-comparison of one spray cone for 5% and 50% OME2 in Diesel at the soot peak.

5% OME2 in Diesel



50% OME2 in Diesel

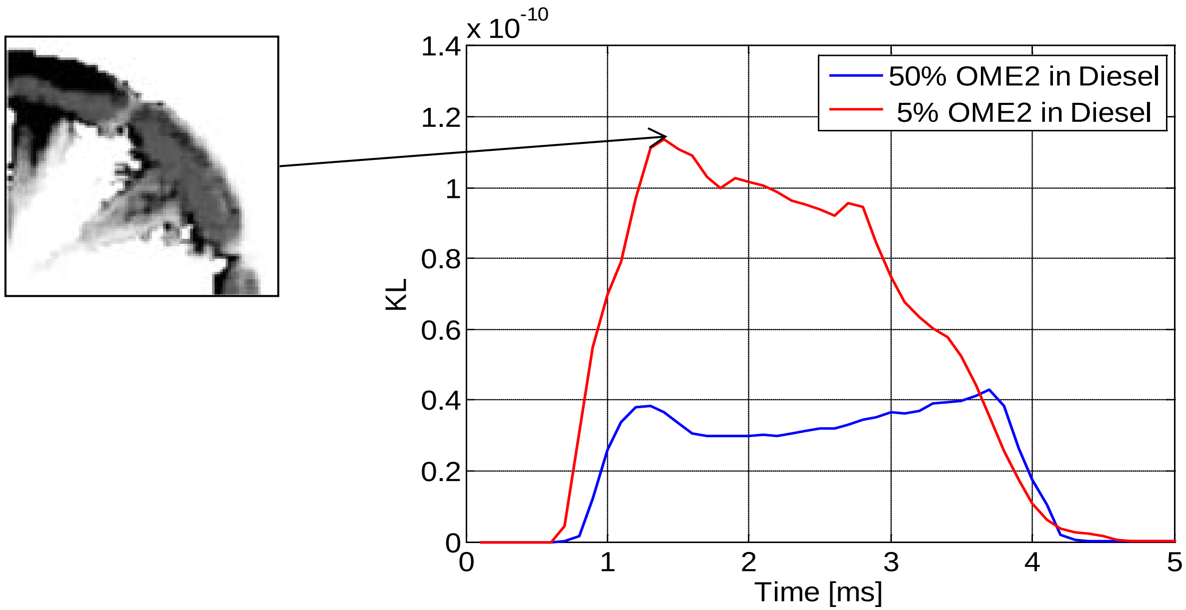


The soot cloud of the 50% blend appears less dense and further away from the injector tip

S. Iannuzzi et al, in prep. 2015

Optical results, 2D-2-Colour Pyrometry

0D-comparison of the soot evolution for 5% and 50% OME2 in Diesel.



- Almost similar soot formation rate
- Early soot oxidation forming a formation and oxidation equilibrium for 50% blend
- Almost similar soot oxidation rate

S. Iannuzzi et al, in prep. 2015

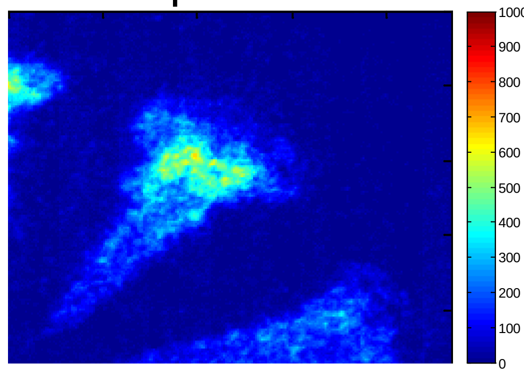
Optical results, OH chemiluminescense

2D-comparison of light at 310 nm (OH-peak) of one spray cone for 5%, 50% OME2 in Diesel and pure OME2 during the injection

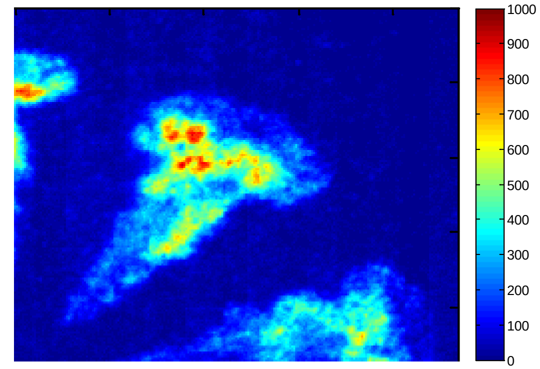
- In the pure case, the OH is not covered by soot sicne (almost) no soot is produced

- The light from the blends contains apparently also radiation, comming from soot.

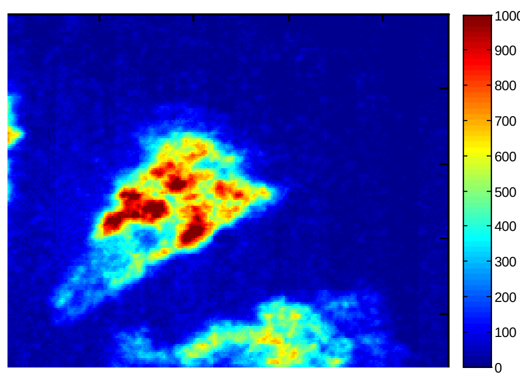
pure OME2



50% OME2 in Diesel



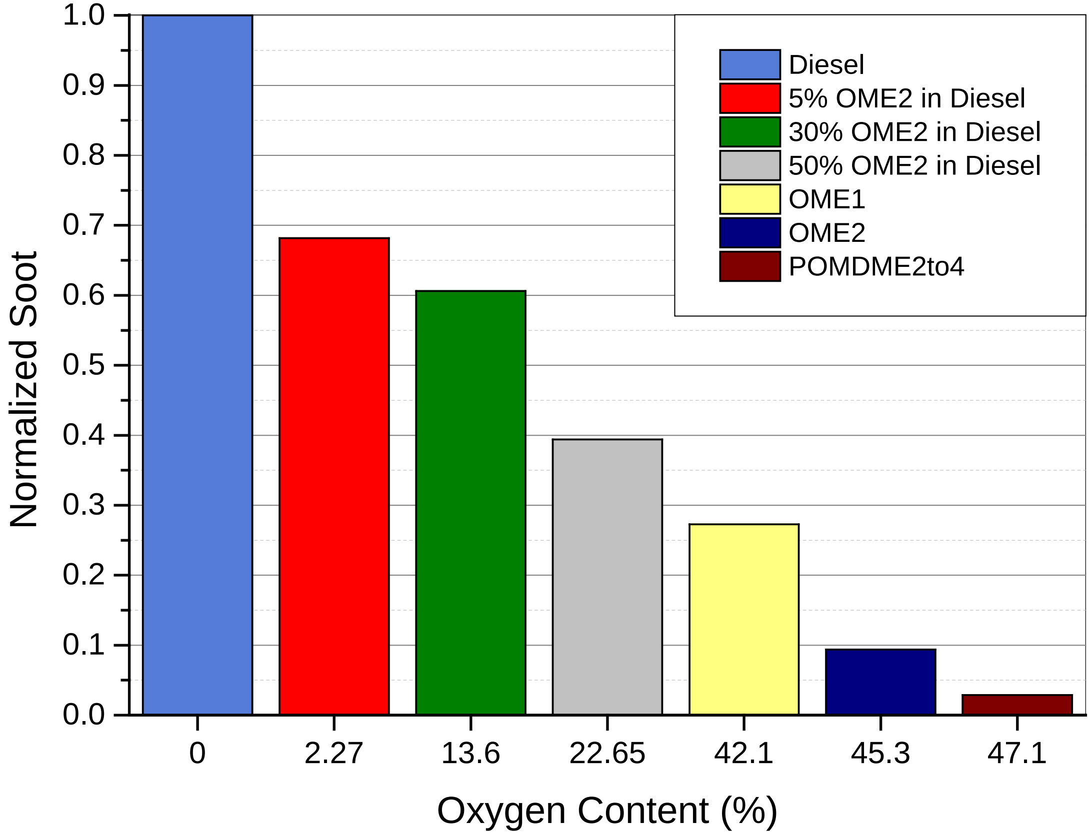
5% OME2 in Diesel



5% OME2 in Diesel: soot

S. Iannuzzi et al, in prep. 2015

Exhaust Soot Results

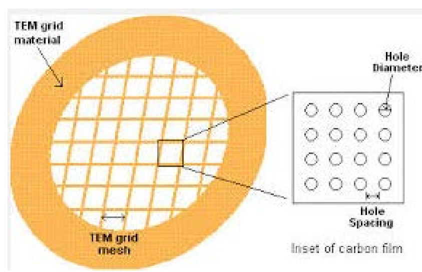


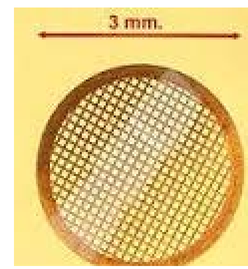
Normalized values to diesel fuel are displayed. A comparison for any investigated fuel is shown at T@SOC=1010K. **A 5% of oxygenated fuel in the blend already gives more than 30% reduction in soot emissions with respect to commercial diesel.**

S. Iannuzzi et al, in prep. 2015

TEM Grid

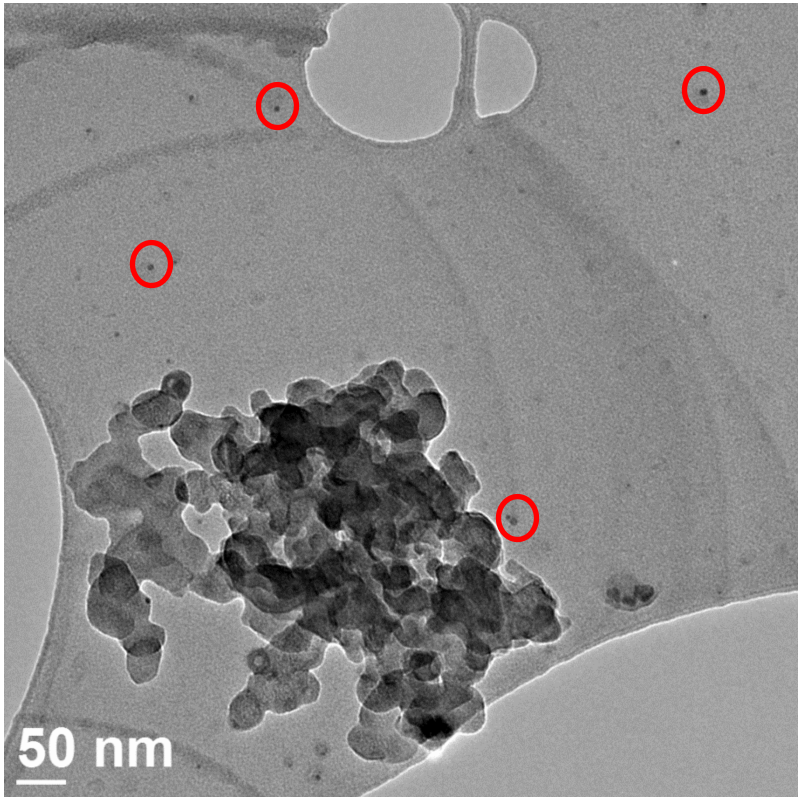
For better understanding of soot formation and oxidation processes, the size, morphology, and nanostructure of soot particles sampled at the constant-volume combustion chamber exhaust have been investigated using Transmission Electron Microscopy (TEM) imaging combined with energy dispersive X-ray (EDX) analysis with both diesel and OME1 fuel.



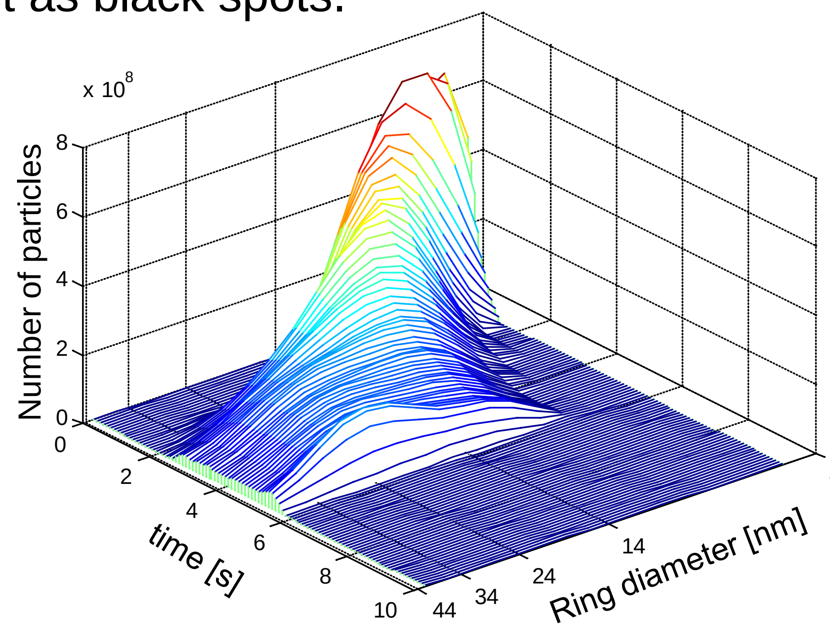


The investigation of primary particle size and soot aggregation can be helpful to characterize and understand the particulate growth and oxidation processes.

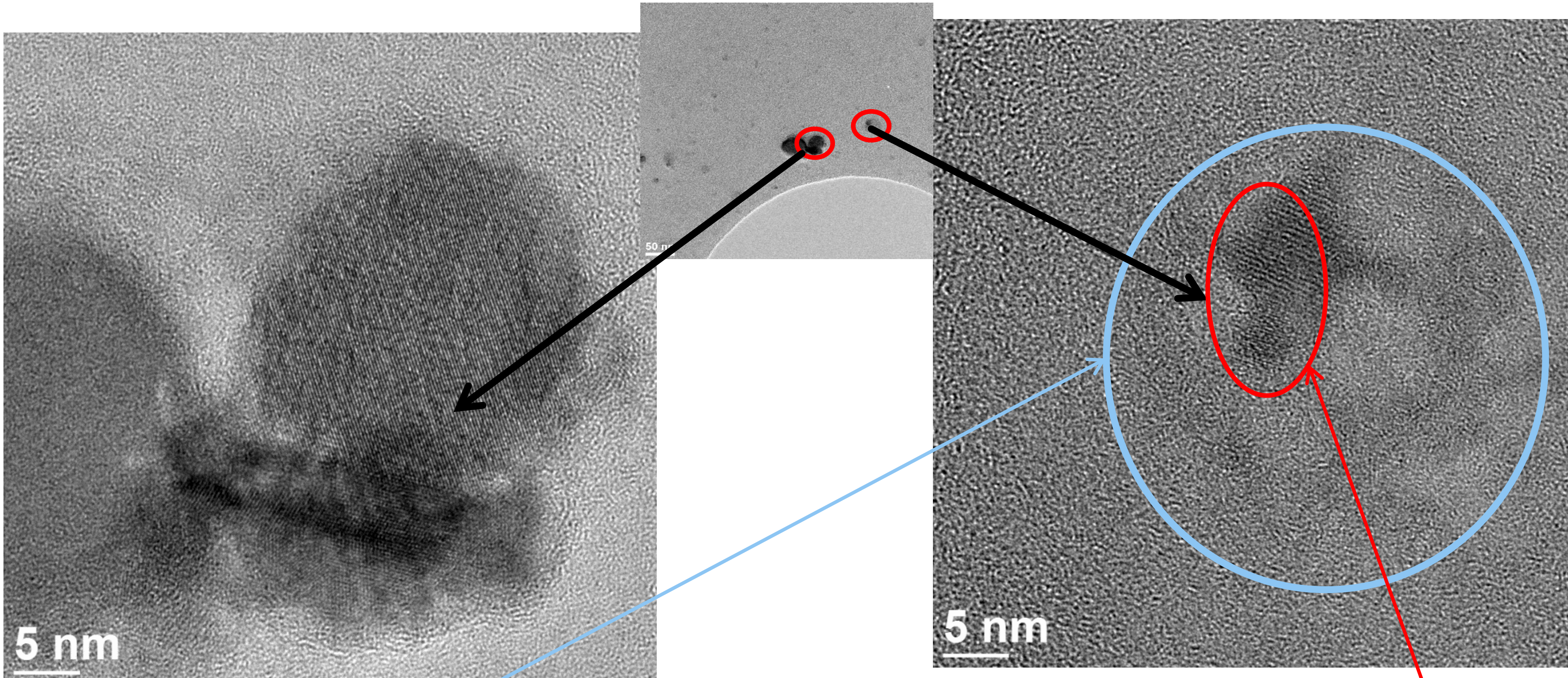
TEM results – OME1



In the case of pure OME1 fuel, instead, a higher number of iron particles have been detected all over the TEM grid. A few of them have been marked with red circles. They appear to be very small with respect to an agglomerate and in a 50 nm scaled images are recognizable just as black spots.



TEM results – OME1



Typical primary soot particles are commonly decorated with a few nm large iron nanoparticles. The iron core is very probably (apparently) coming from wear of the injection system.

Summary & Conclusions

Different oxygenated, diesel-like fuels (i.e. OME) have been investigated using a constant volume combustion chamber

1. In-cylinder study:
   - In-cylinder soot concentration is reduced due to earlier soot oxidation with higher oxygen content in the fuel

2. Exhaust measurements:
   - Lower soot mass with higher oxygen content in the fuel
   - High exhaust soot reduction with already low oxygen content in the fuel

3. TEM study using OME1:
   - Significantly reduced amounts of sampled soot
   - Iron nanoparticles presumably act as nucleation cores for additional soot formation

Acknowledgements

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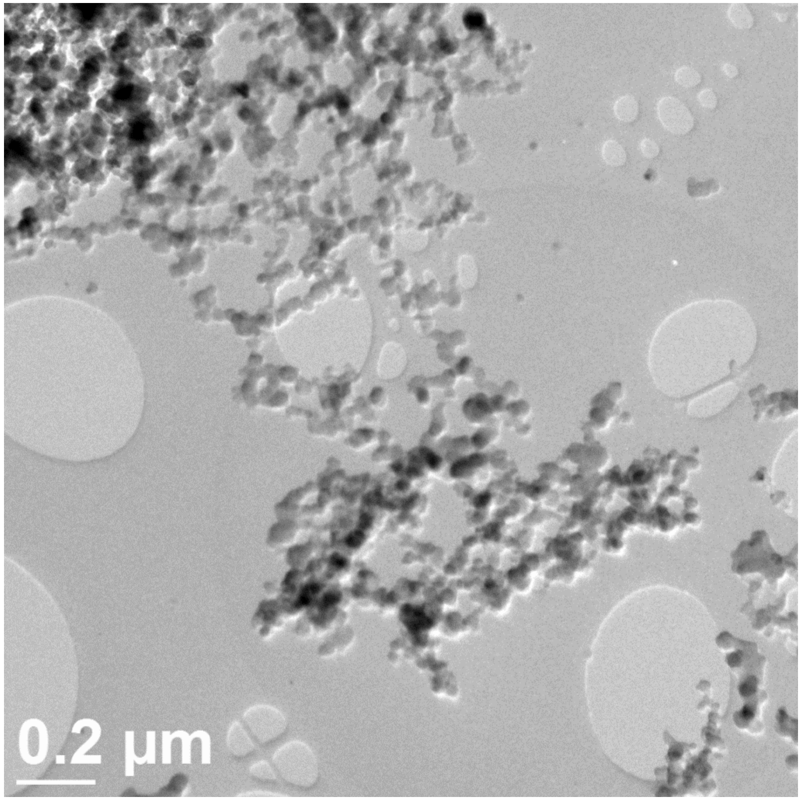
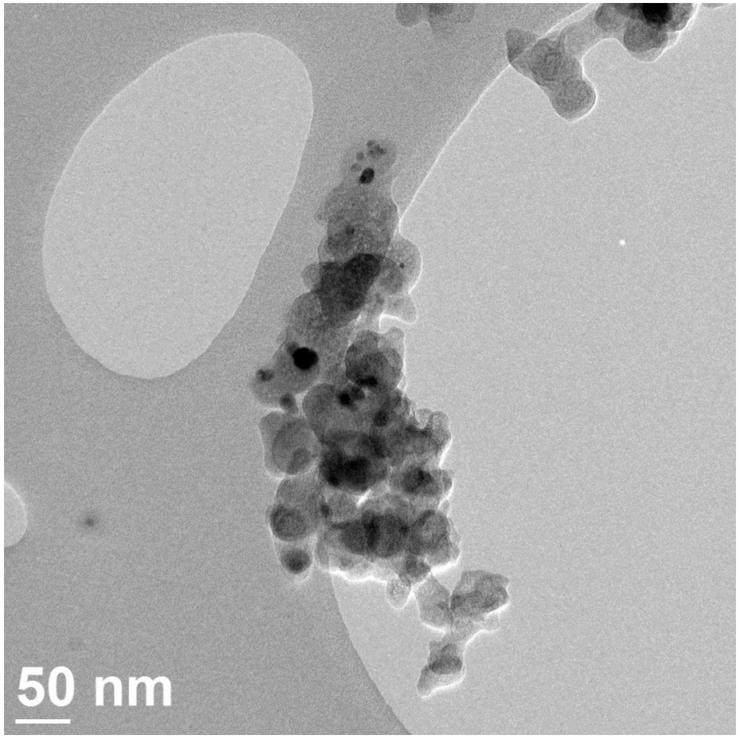
- J. Renner, INEOS Paraform GmbH & Co
- Swiss Federal Office of Energy

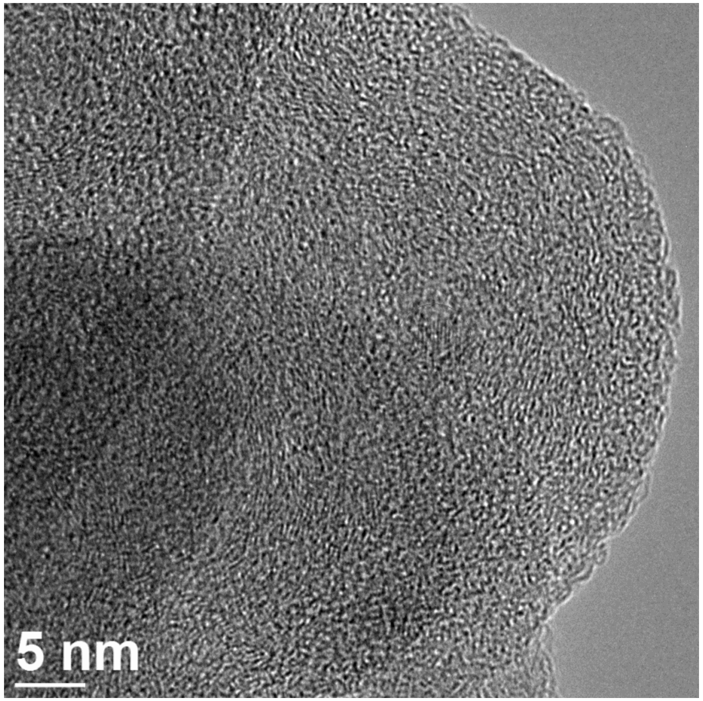
Backup TEM results - Diesel



Investigation from primary particles to relatively wide agglomerates is possible.
Several soot agglomerated structures can be seen in the image and few iron particles are detected.

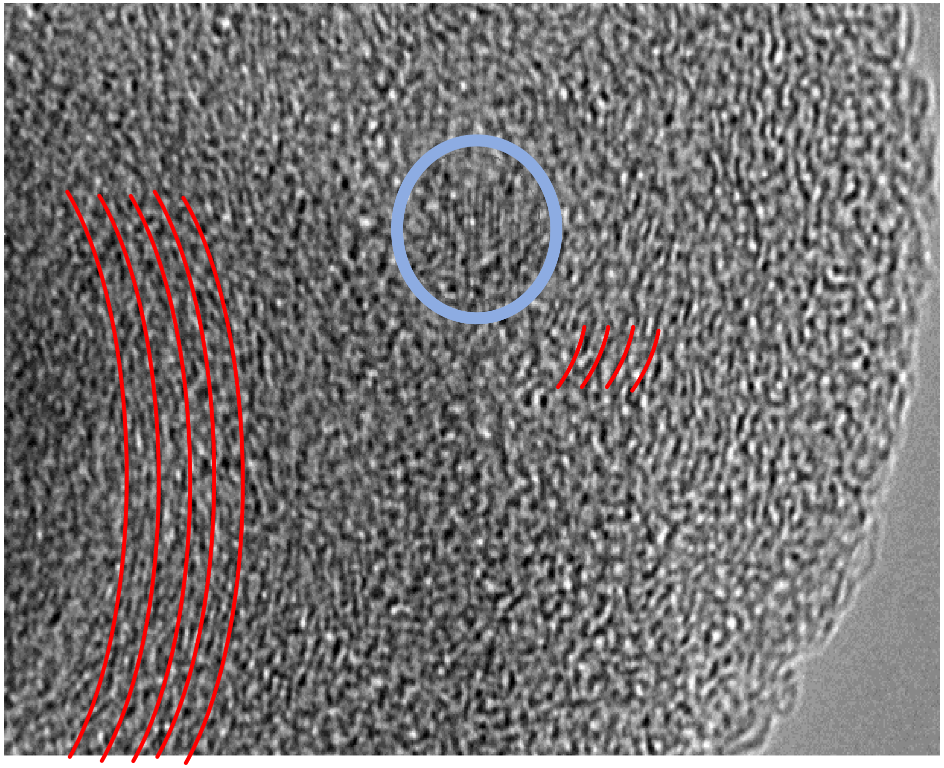
Backup TEM results - Diesel





The left side image shows soot agglomeration containing several iron cores one of which is circled in the zoomed-in right side image.The fact that the iron core is on the same focus plane as the surrounding soot structures brings to consider that the iron particle might sit on the same level.

Backup TEM results - Diesel



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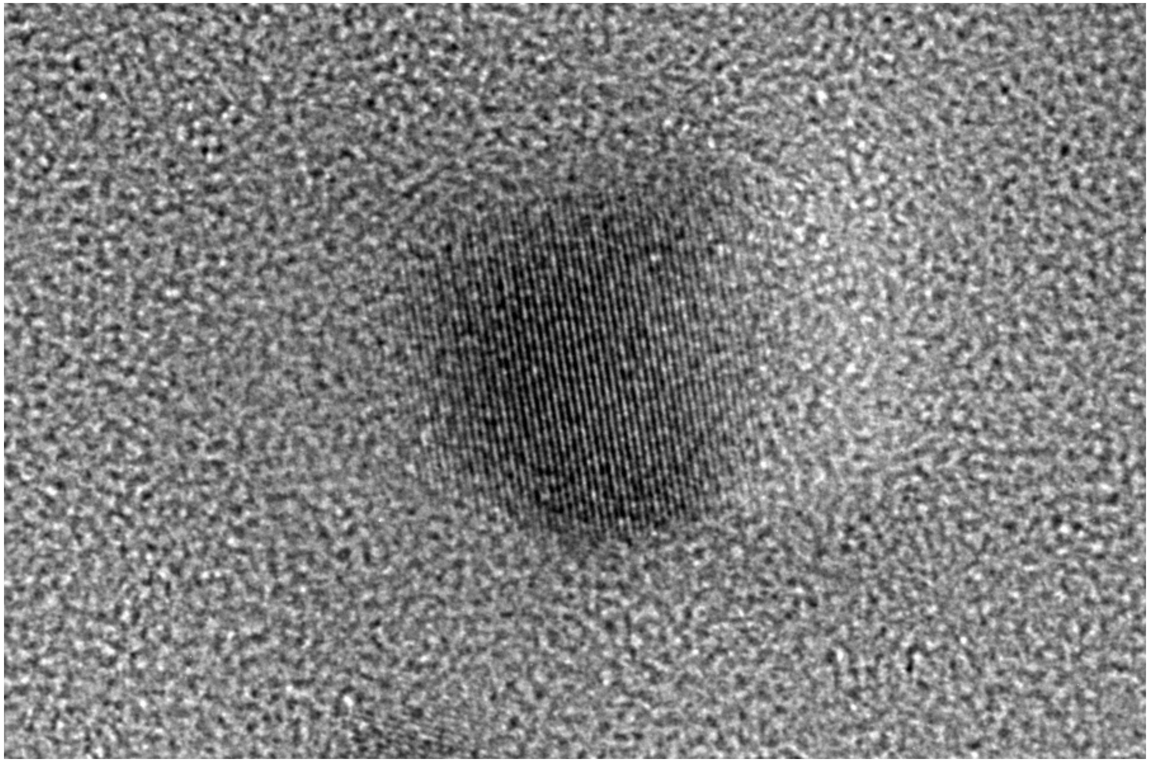
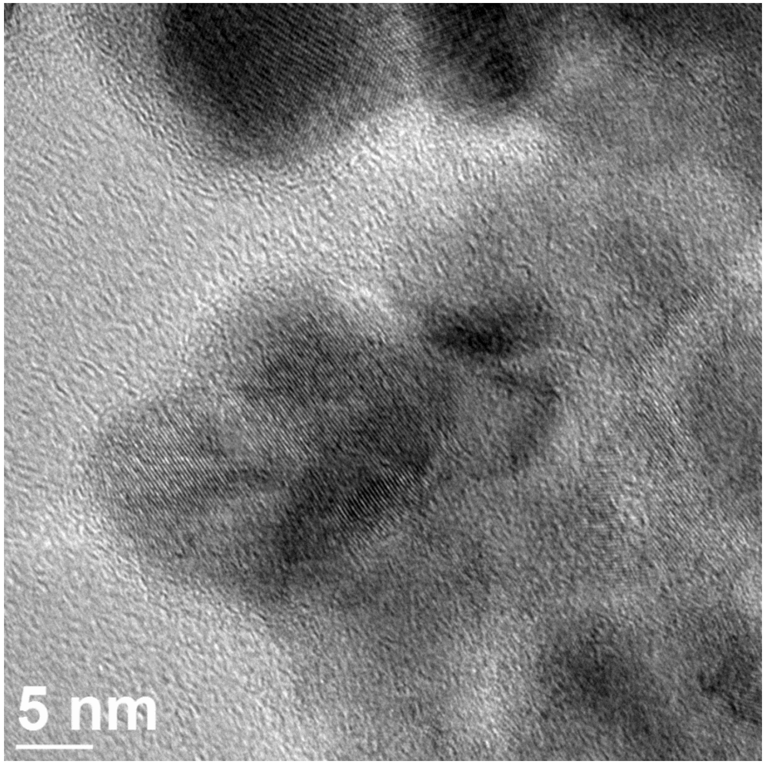
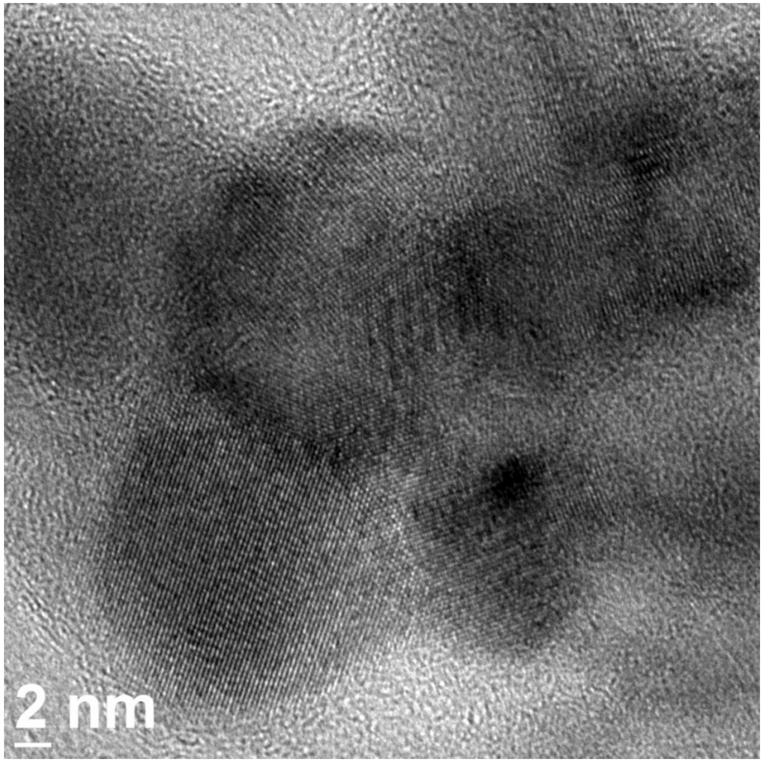
Backup TEM results - Diesel



The image above further clarifies the iron lattice fringes.

Backup TEM results – OME1





Both images here further give the chance to identify the lattice fringes of iron nanoparticles on a same level (or focus plane) as the soot particles.