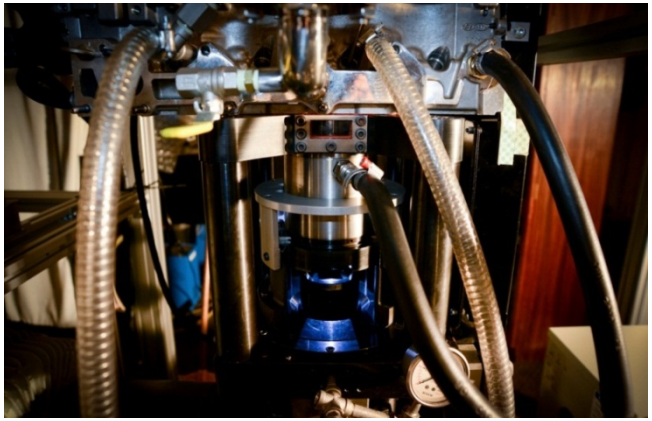
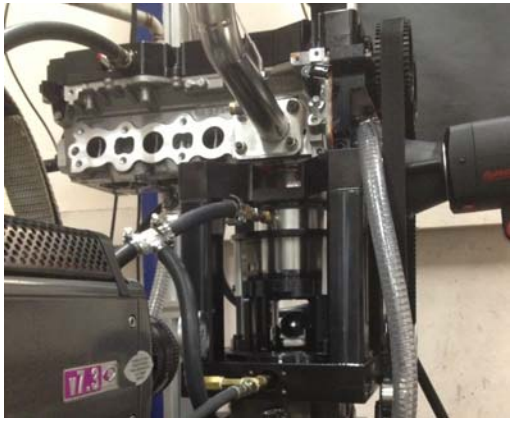

In-flame soot particles in an automotive-size diesel engine

Sanghoon Kook, PhD
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***Academic-in-Charge*, Engine Research Lab**
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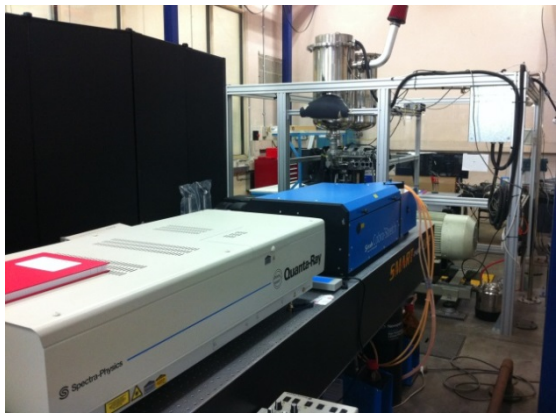
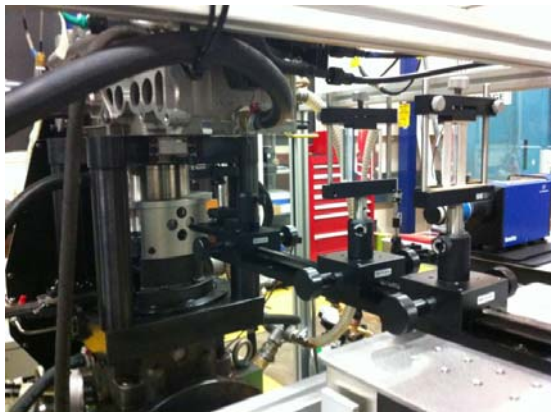
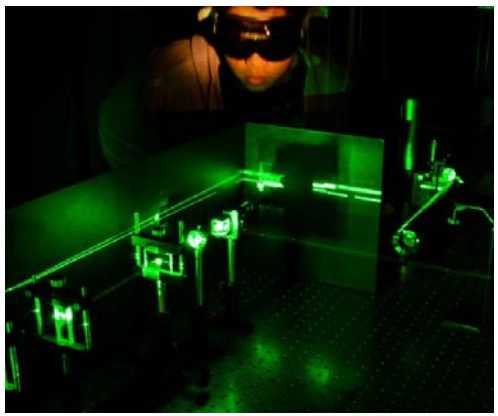
Never Stand Still | Faculty of Engineering

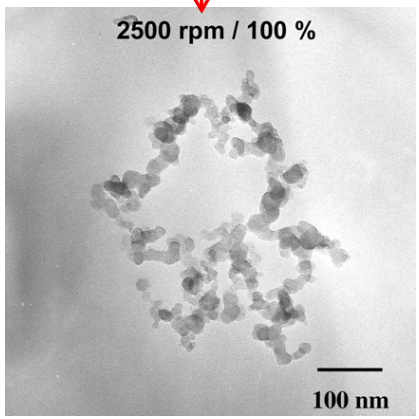


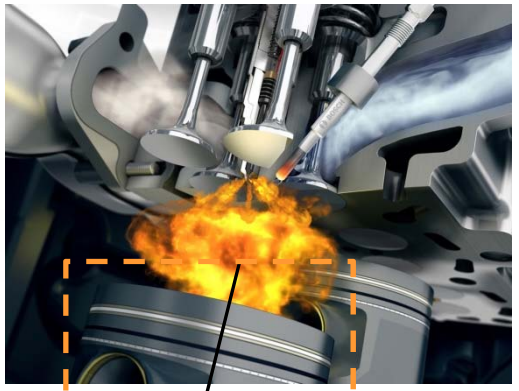
ETH Soot Conference on 23 Jun 2014 (11:50-12:10)

We know about exhaust soot particles but have a limited understanding on in-flame soot.

Cambustion DMS500 for "mobility diameter"

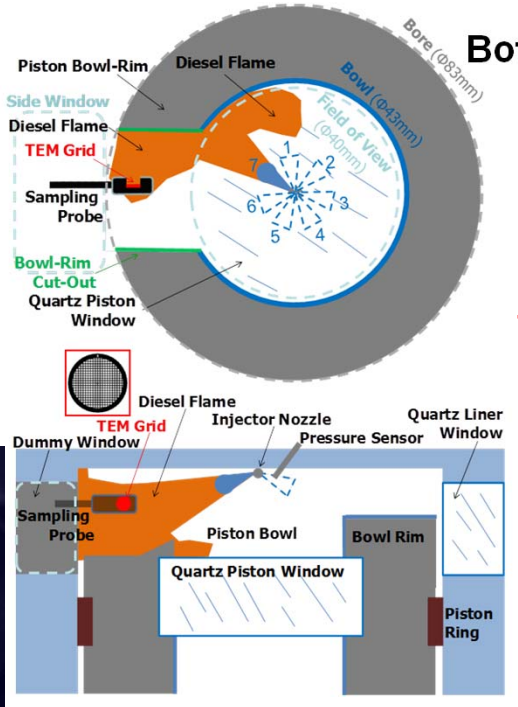


Morphology of exhaust soot particles (Zhu et al, 2005)



How would soot particles here look like?

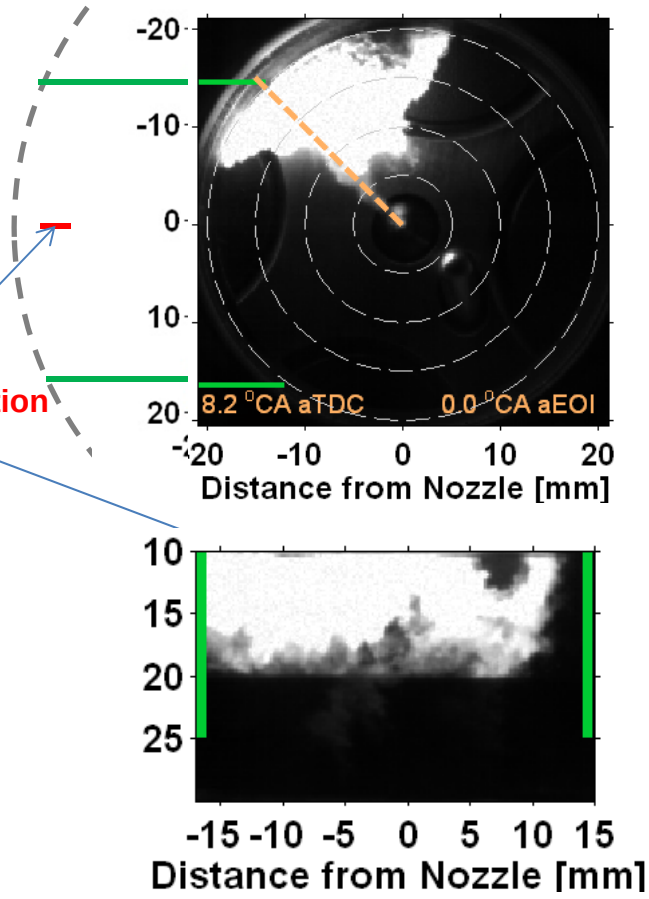
“Hot soot” luminosity movies suggest successful sampling of soot particles.



Bottom view

Side view

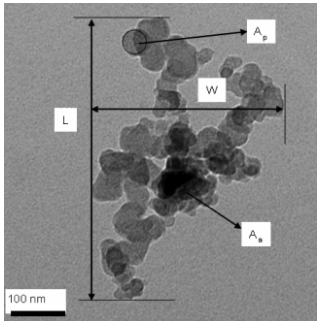
TEM grid location

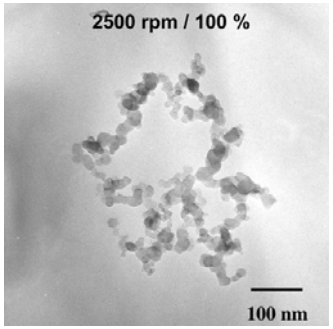


The sampler design, cyclic variations, soot exposure time, soot overloading, image processing details are found:

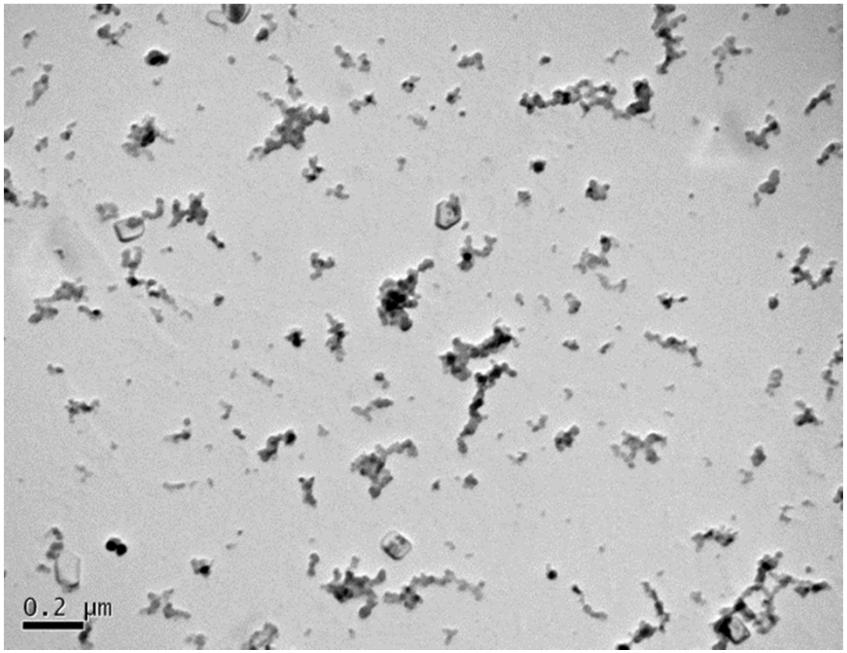
Kook S., Zhang R., Szeto K., Pickett L.M., Aizawa T., “In-flame soot sampling and particle analysis in a diesel engine,” **SAE** International Journal of Fuels and Lubricants 6(1):**2013-01-0912**, 2013.

Soot images exhibit similar shapes and structures of those collected in the exhaust.



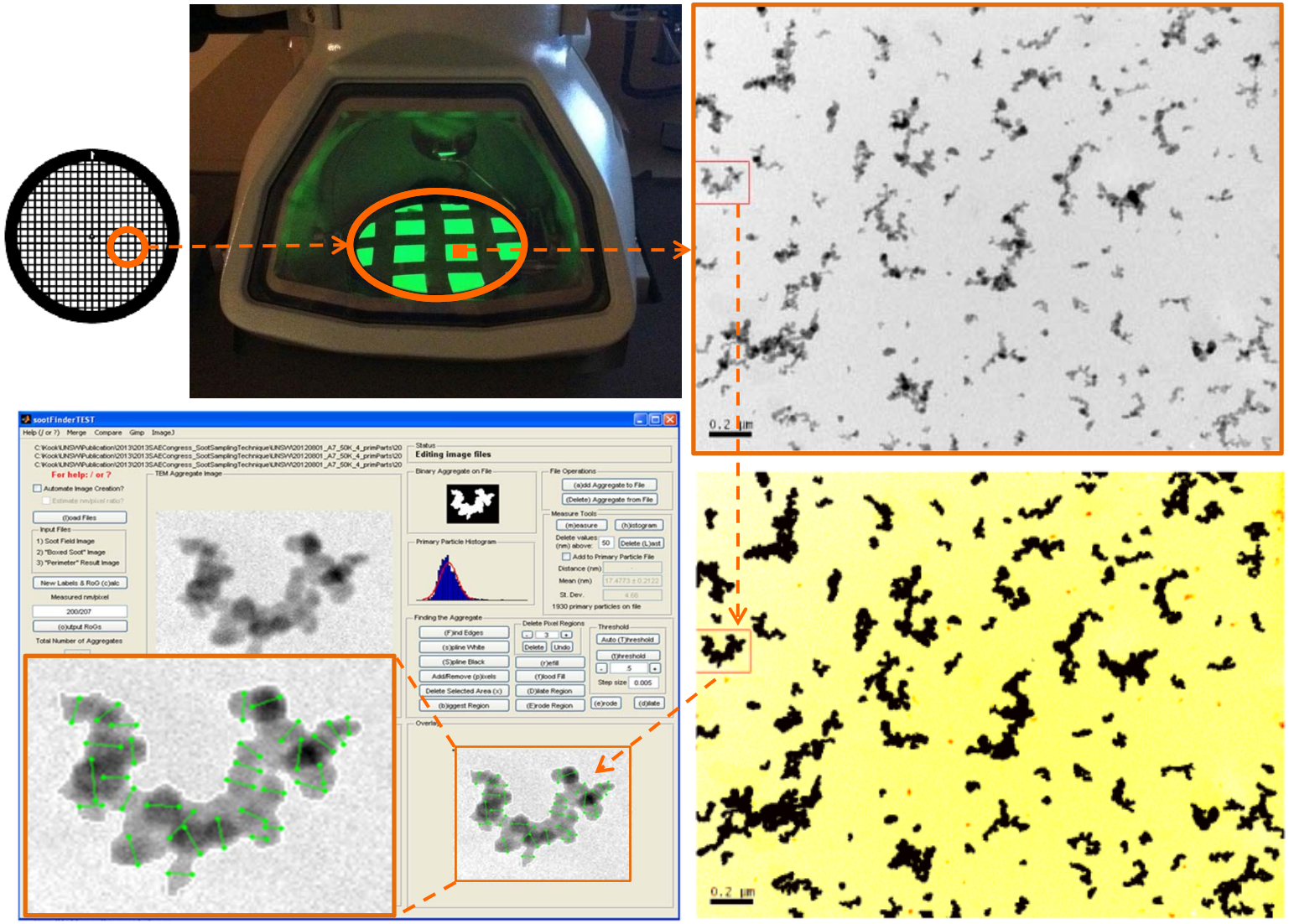


Exhaust soot particles
(Park et al, 2004) **(Zhu et al, 2005)**



In-flame soot particles inside the engine cylinder
(Present study)

Post-processing of soot particle images…

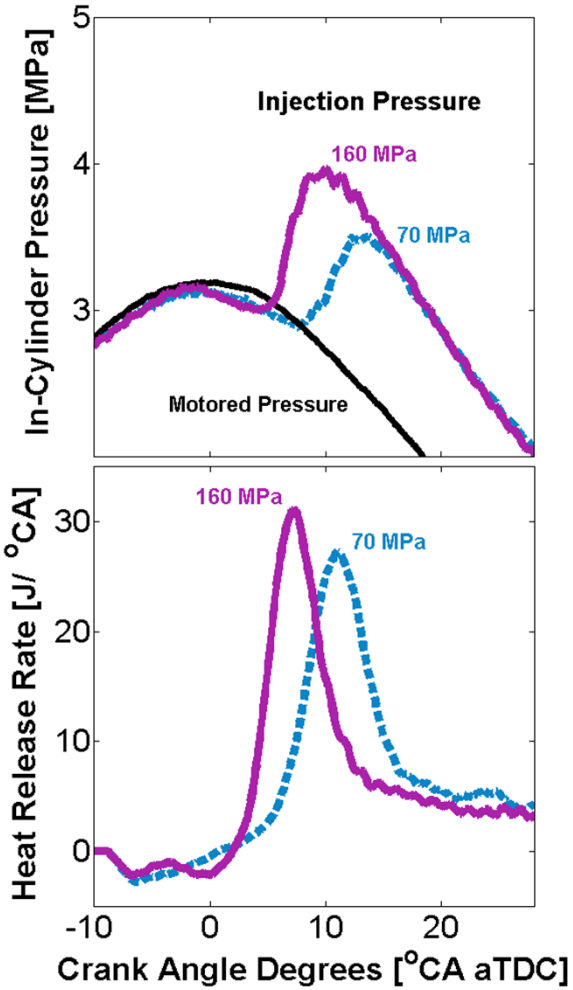


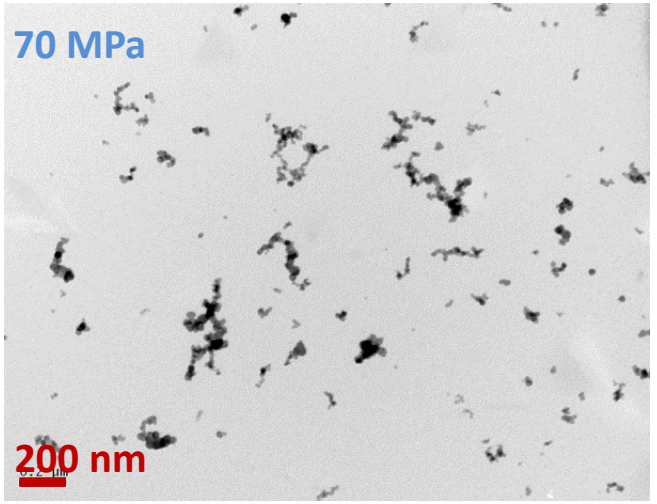
What is the practical value of this in-flame soot sampling technique?

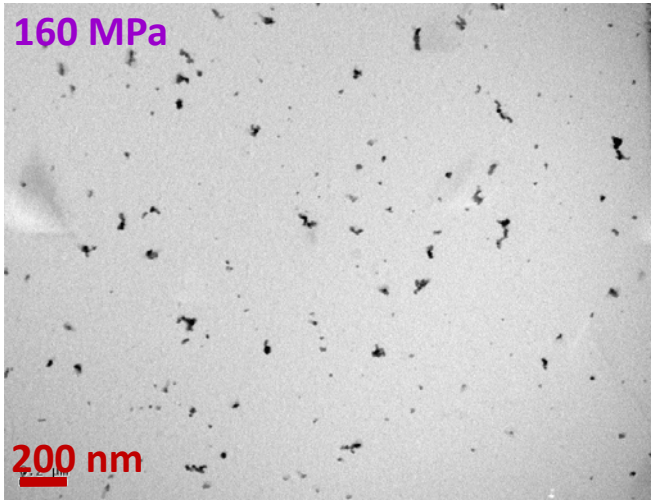
A good case study is here: injection pressure variation.

Distinct global phenomena

Sampled soot particles appear to be very different.







Detailed discussions are found in:
R Zhang and S Kook, "Influence of Fuel Injection Timing and Pressure on In-flame Soot Particles in an Automotive-Size Diesel Engine," **Env Sci Tech** (in press)

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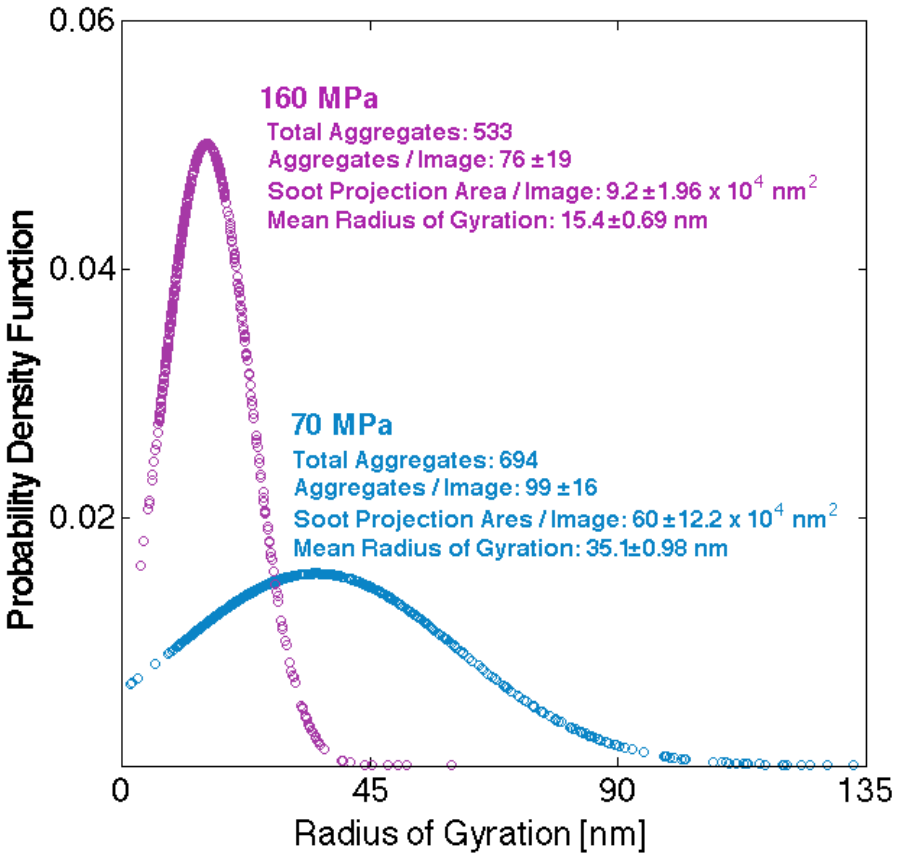
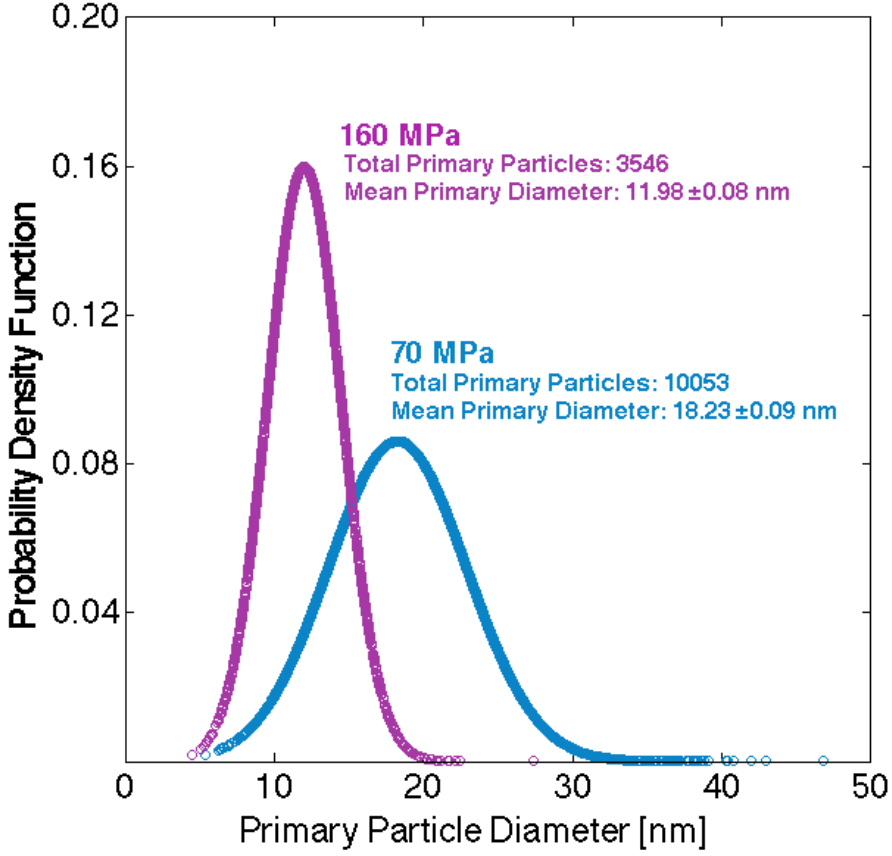
Aggregates are smaller and the primary diameter is lower for higher injection pressure.





High injection pressure results in not only less number/amount of soot particles but also smaller soot aggregates and primary particles.

Detailed discussions are found in:
R Zhang and S Kook, "Influence of Fuel Injection Timing and Pressure on In-flame Soot Particles in an Automotive-Size Diesel Engine," **Env Sci Tech** (in press)

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Further application for the soot particles evolution during wall-interacting diesel flame development

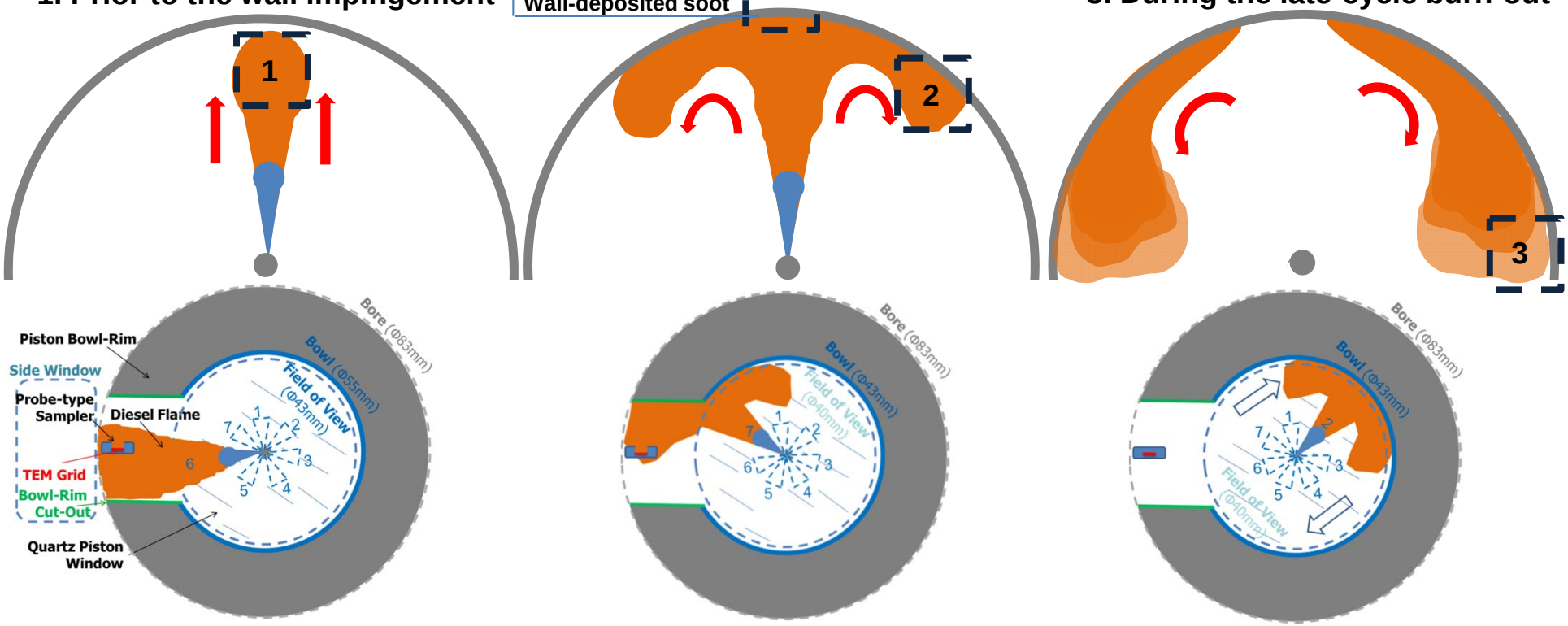
*SAE 2013-01-2534

1. Prior to the wall impingement

Wall-deposited soot

2. After the wall impingement

3. During the late-cycle burn-out



And then 4. Engine-out soot

*Zhang R., Szeto K., and Kook S., "Size distribution and structure of wall-deposited soot particles in an automotive-size diesel engine," **SAE** International Journal of Fuels and Lubricants 6(3):**2013-01-2534**, 2013.

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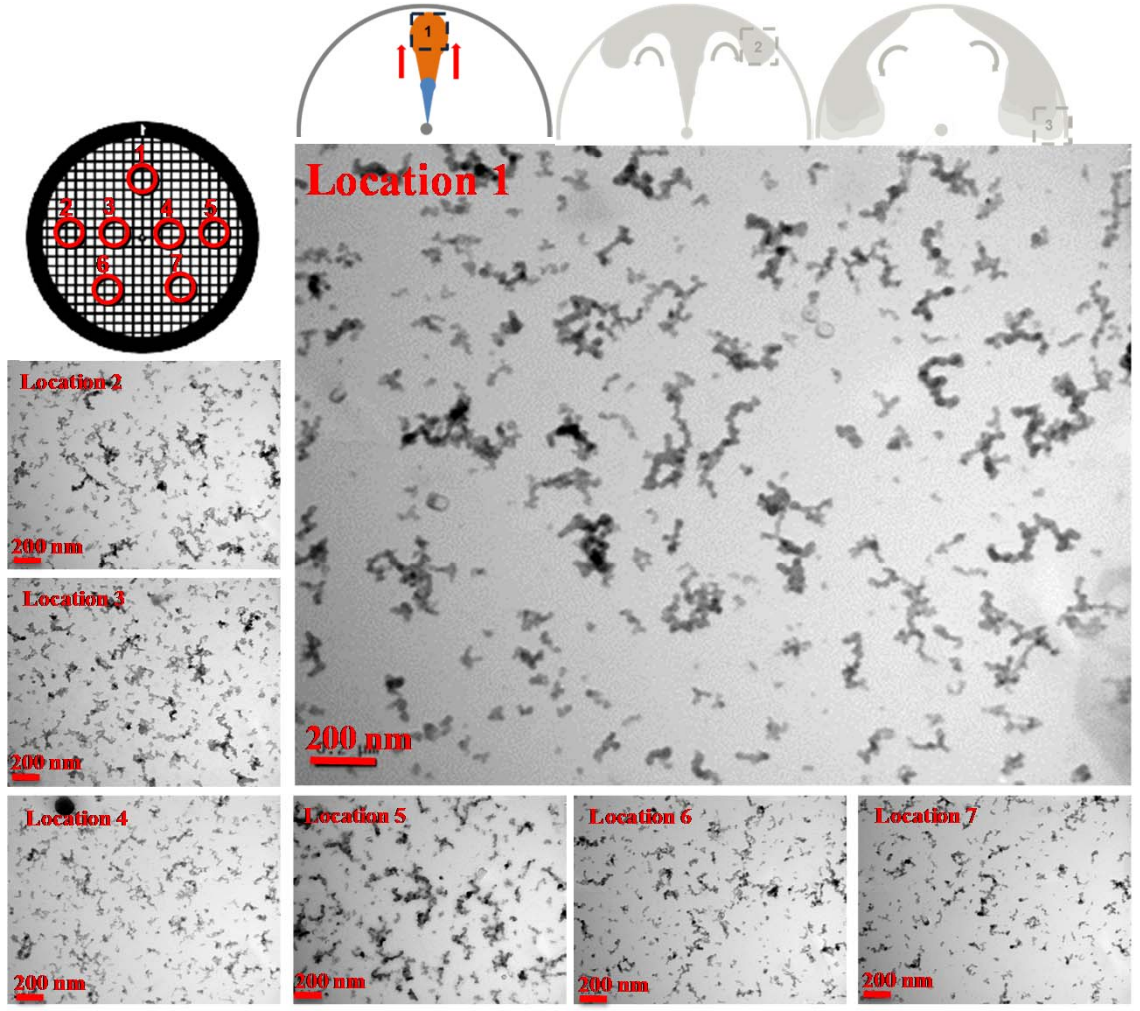
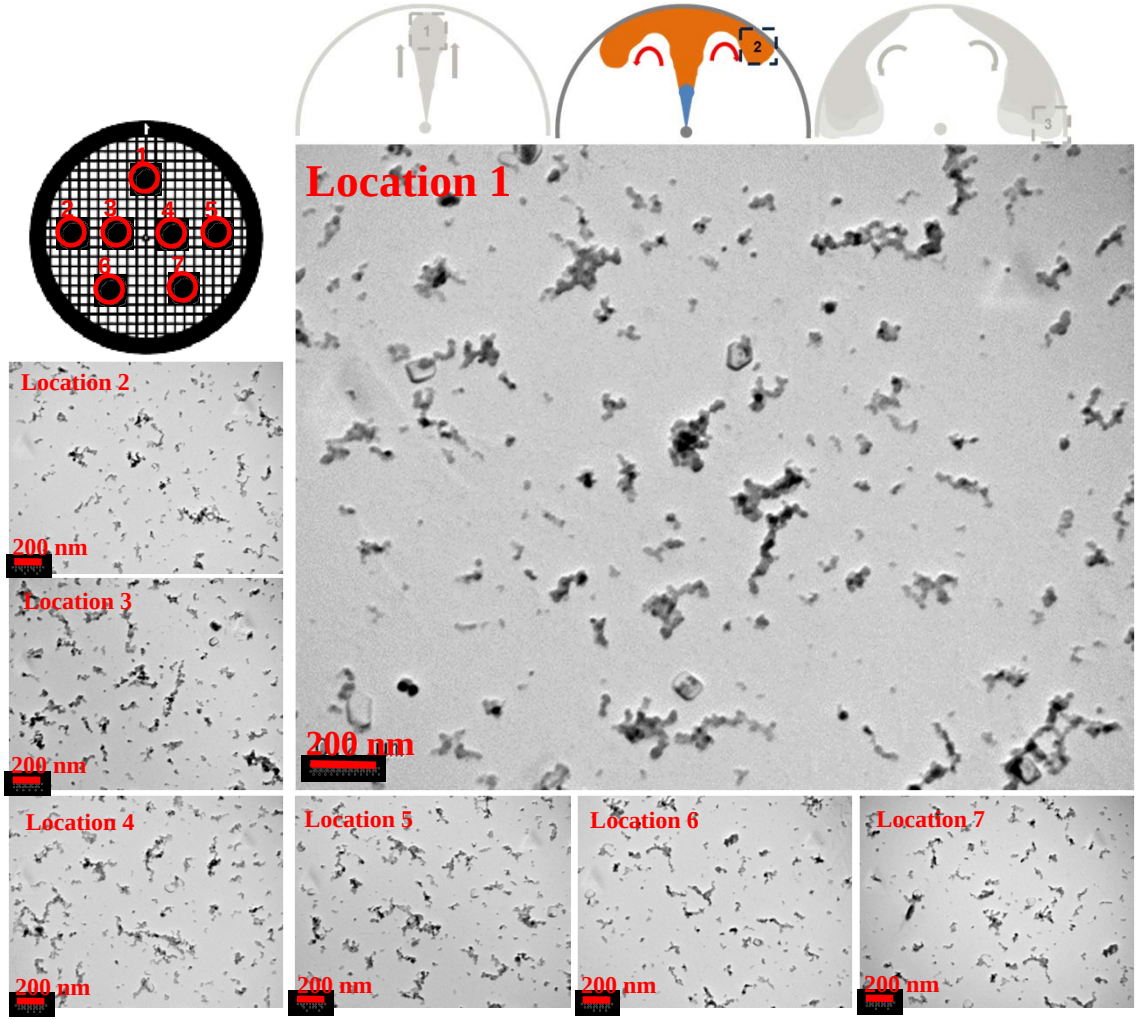
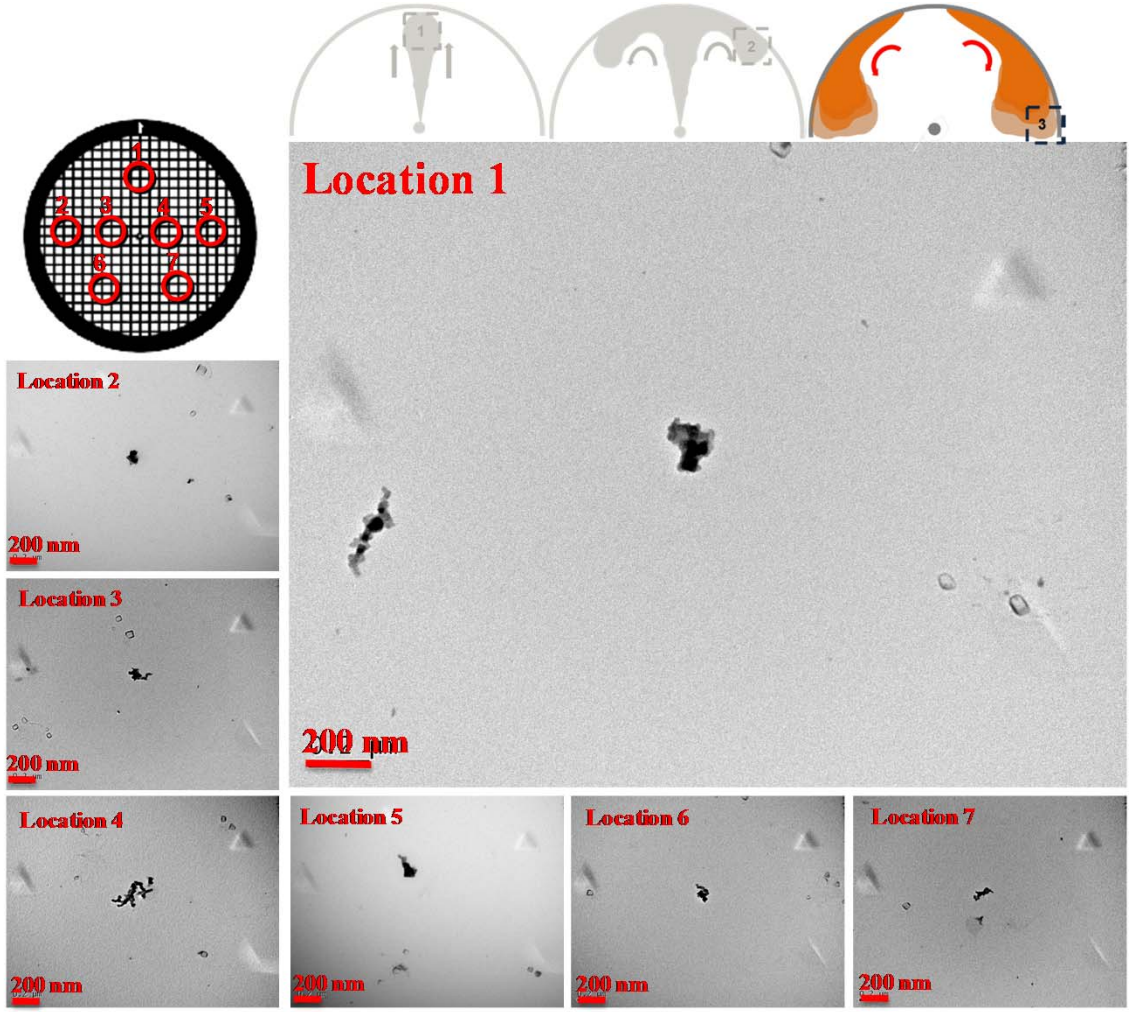
Stage 1: In-flame soot particles prior to the wall impingement



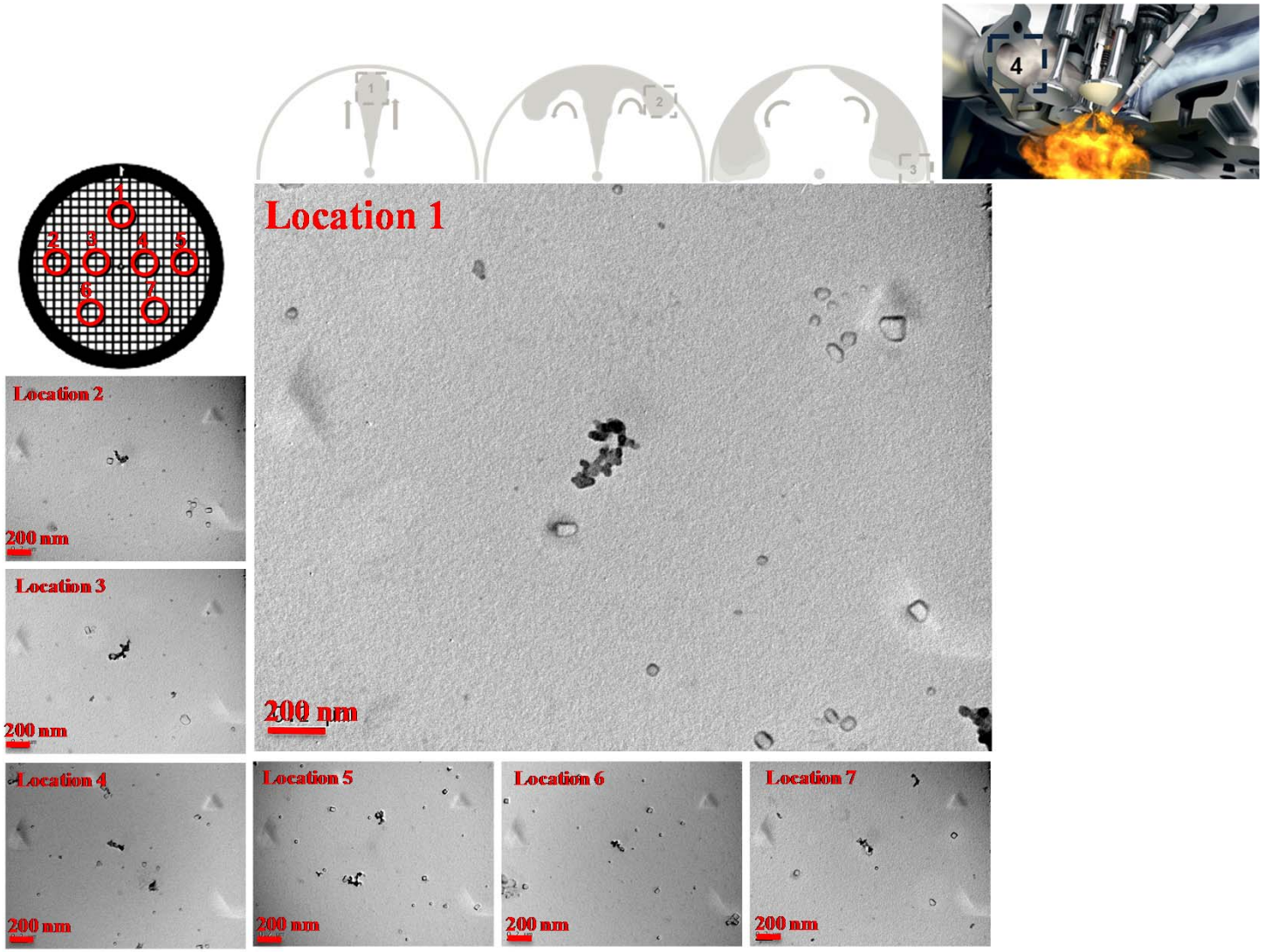
Stage 2: In-flame soot particles after the wall impingement



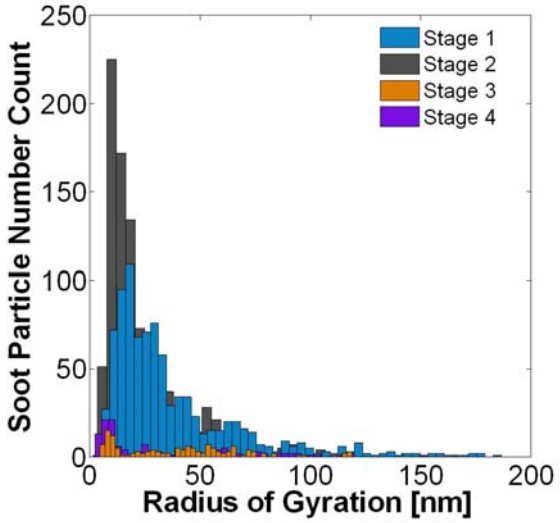
Stage 3: Soot particles at the late-cycle burn-out (soot oxidation) stage



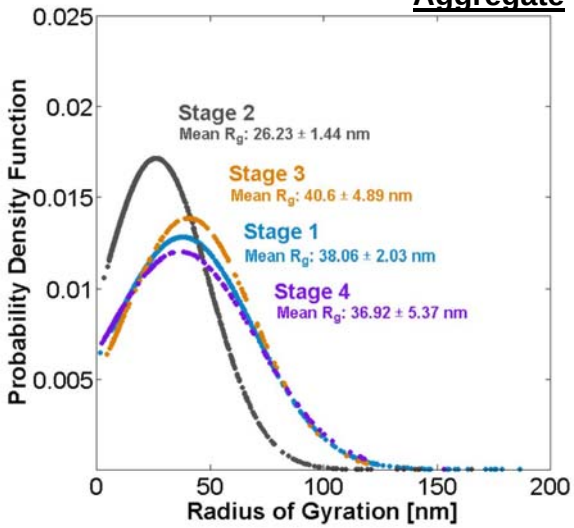
Stage 4: Engine-out soot particles



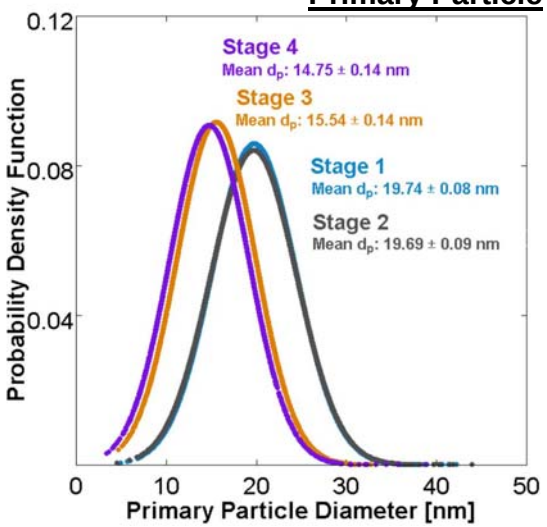
Statistical analysis for the size and structure of soot particles (aggregates and primary particles)

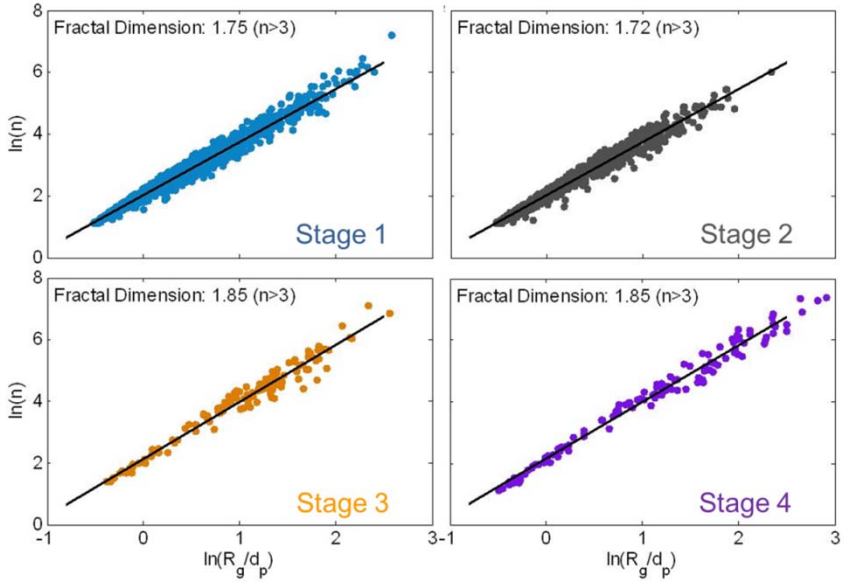


Aggregate



Primary Particle





Breakdown of soot aggregates due to the flame-wall interaction (Stage 1-2)

- ✓ Decreased R_g due to the increased number of small aggregates and decreased number of large aggregates .
- ✓ No change in d_p and overall fractal dimension.

Soot oxidation between the main combustion and late-cycle burn-out (Stage 2-3)

- ✓ Decreased d_p
- ✓ Increased R_g due to the disappearance of small aggregates.
- ✓ Increased fractal dimension (more compact aggregate shape)

Similarity between the late-cycle soot and engine-out soot (Stage 3-4)

- ✓ The decrease of R_g and d_p suggests further oxidation but it is very minor and the fractal dimension does not change.

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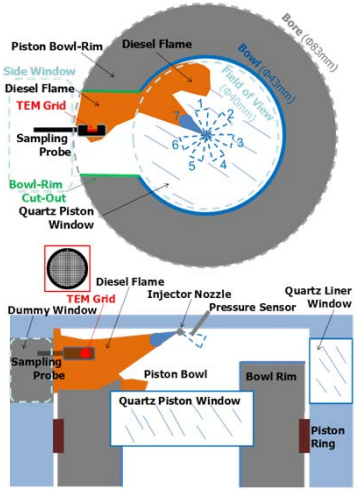
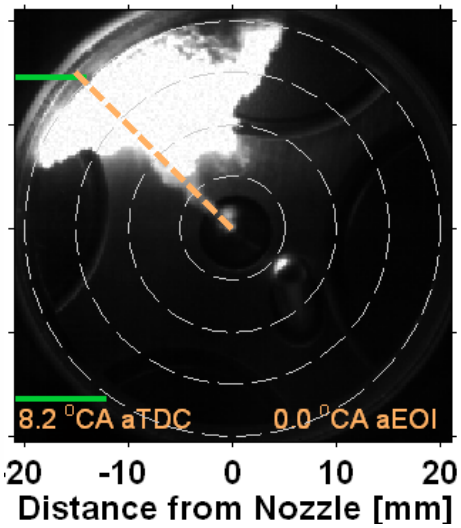
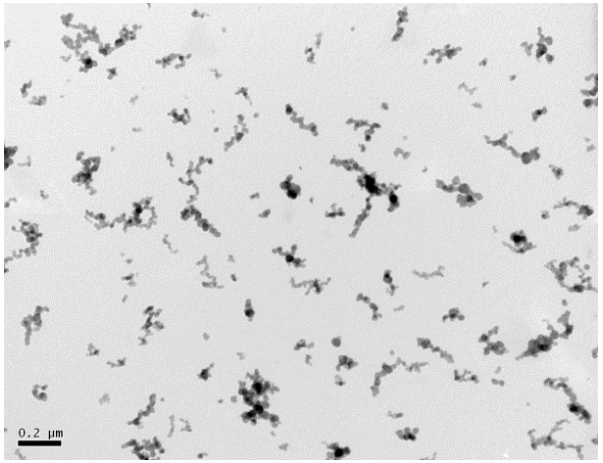
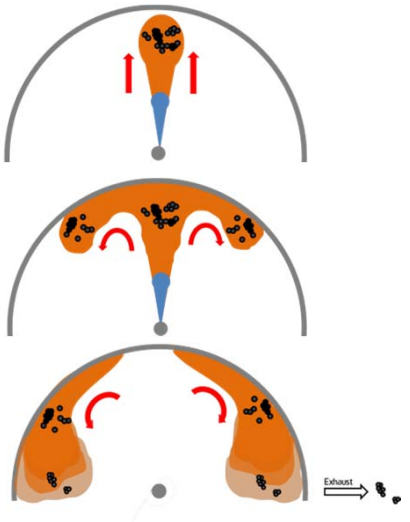
Summary









- Soot particles are sampled directly from a diesel flame in a working diesel engine.
- Soot aggregates with various sizes and structures form within the diesel flame, which breakdown and become smaller during the flame-wall interaction.
- The large aggregates further breakdown, small aggregates disappear completely, and the primary particles become smaller due to the continued oxidation throughout the late-cycle burn-out.
- The remaining aggregates are very concentrated, agglomerated, and compact, which are emitted to the exhaust.