Estimation of the SOA-formation potential in emissions from GDI engines

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Summary

•We present first results from the determination of the secondary organic aerosol production potential of gasoline direct injection (GDI) vehicles.

•We use a flow reactor, the Micro Smog Chamber, to expose the gas-phase emissions of the GDI vehicles to high intensity UV light. This reduces the volatility of the organic fraction and, in the absence of seed aerosol, results in a nucleation mode formed exclusively of secondary aerosol. The nucleation mode can be measured by means of a nano-SMPS system during steady state conditions.

•Our aim is to establish an average size distribution of the secondary emissions generated in our system and then use a much faster particle counting technique to establish a real time (seconds resolved) emission factor during transient cycles.

•The micro smog chamber is up to our knowledge the system with the fastest oxidation of secondary aerosol precursors and thus achieves the best time resolution.

•This is the first time that our system has been tested with vehicle emissions. Nevertheless, we have a clear signal originating from secondary aerosol.

•The level of potential secondary emissions per amount of fuel is several orders of magnitude lower than what we have observed in wood burning experiments (our standard test system).

The GasOMeP Project

In the next decades to come, we will be exposed to exhausts of gasoline direct injection (GDI) vehicles with yet unknown consequences. In the GasOMeP (Current Status and New Concepts of **Gas**oline Vehicle Emission Control for **O**rganic, **Me**tallic and **P**articulate Non-Legislative Pollutants) project, we investigate the emission characteristics of various GDI vehicles and evaluate the potential of gasoline particle filters (GPFs) currently developed by our industrial partners. The three-year project will result in a comprehensive characterization of GDI vehicle emissions and evaluate the potential of new filter technology to abate potentially harmful exhaust constituents. The project is a joint effort of the industry, regulators, and the Swiss research institutions PSI, the Universities of Applied Sciences and arts Northwestern Switzerland and Bern, and EMPA.

Within the framework of GASOMEP, secondary organic aerosol (SOA) forming potentials are being investigated with smog chamber experiments, executed PSI Switzerland, and two independent flow reactor approaches. One of them, the micro smog chamber designed by the University of Applied Sciences Northwestern Switzerland, is different to traditional aging experiments in that we concentrate exclusively on the formation of secondary aerosol by taking the gas-phase fraction of the emissions and oxidize it using ozone concentrations up to 60ppm. The residence time at this high oxidant concentration is of the order of 10 seconds.

References (Micro Smog Chamber)

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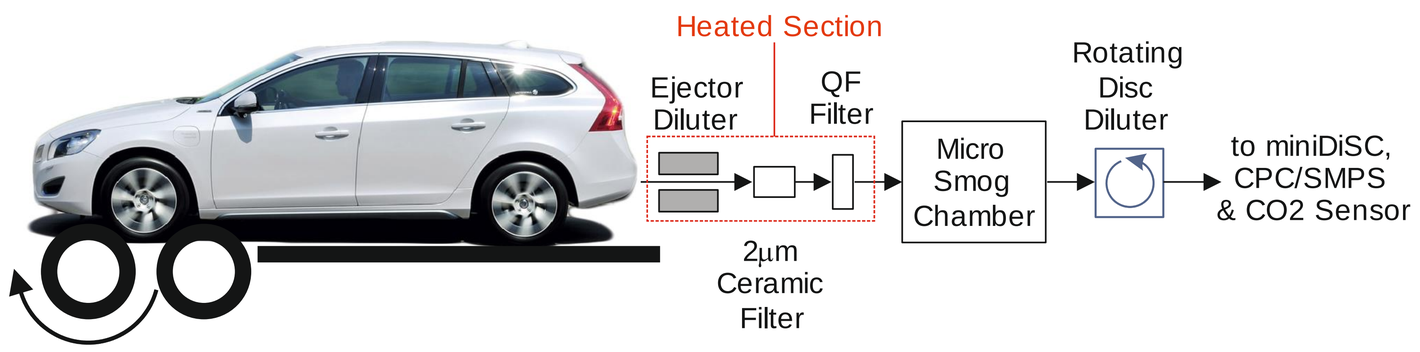

Figure 1. Experimental setup. Samples are extracted during a standard driving cycle (world harmonized light vehicle test cycle, WLTC) or during steady state conditions (constant speed or idle). Only the gas-phase fraction (dilution ~1:10 and 150° C) is oxidized inside the micro smog chamber. On a second dilution stage the concentration is reduced to levels compatible with our aerosol measurement devices.

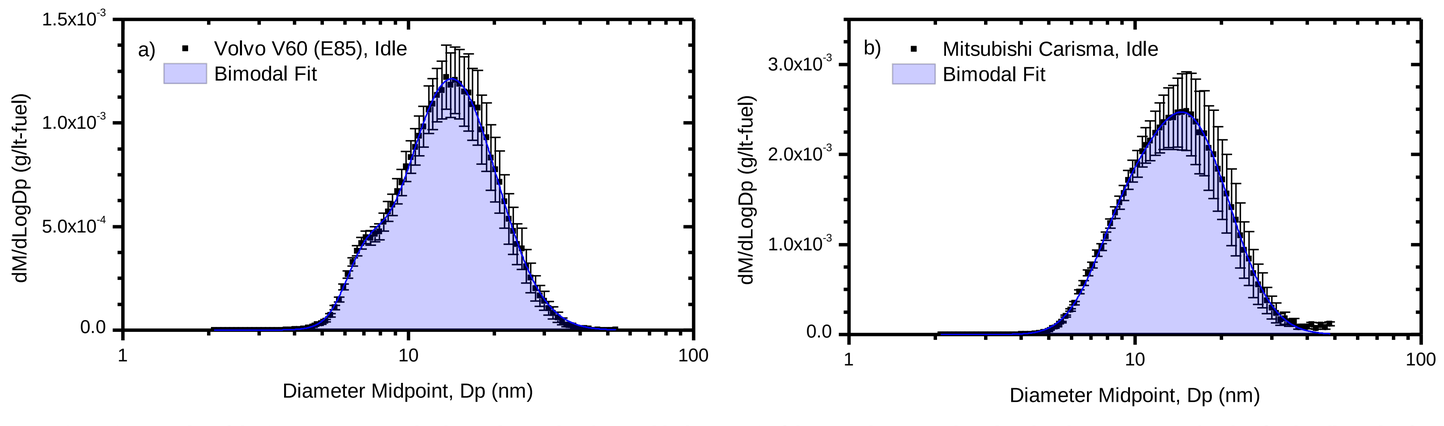

Figure 2. Examples of the Average mass-weighted particle size distribution (black squares) of the secondary aerosol produced in the micro-smog chamber for the idle cycle of two GDI vehicles: a) Volvo V60 (EURO 5) using an 85% ethanol - 15% gasoline mixture and b) Mitsubishi Carisma (EURO 3) running on 100% gasoline. Error bars show the standard error of the mean. The integral of the fitted curve (shaded area) can be used to calculate an average emission factor for the secondary aerosol. A particle density of ρ=2000 kg/m^3 was used for these calculations.

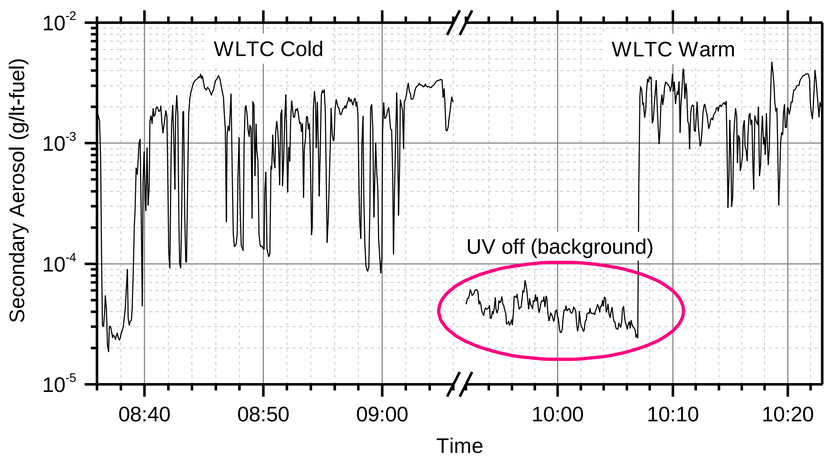

Figure 3. Examples of secondary aerosol produced in the micro-smog chamber during cold-start and warm-start world harmonized light vehicle test cycle (WLTC). The mass concentration was derived from the number concentration by using average mass distributions from steady state conditions. The UV light was off during the first half of the warm cycle and, thus, no secondary aerosol was produced.

Next steps / Points to be investigated

•Comparison of the micro smog chamber results against smog chamber and the other flow reactor (PAM chamber).

•Estimation of particle losses inside and after the micro smog chamber (losses are critical for nucleation mode particles).

•Can transient cycles be predicted based on results from steady state? (comparison against PAM chamber may help answer this)

•Is linearity a good approximation? Currently, the particle size is assumed to be constant and, thus, particle number is used as surrogate of particle mass. First results from steady state conditions suggest that this is a reasonable assumption.

•Our mass size distributions are all bimodal. Could the two modes come from a mixture of SOA and another secondary aerosol?

Acknowledgments

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