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Publication title	Highly sensitive NO2 detector for selective air pollution monitoring
Publication type	Poster
Introduction & Background	Nitrogen dioxide (NO2) is a major air pollutant generated through combustion of fossil fuels in stationary sources and motor vehicles. Exposure already at low parts-per-billion levels per volume leads to respiratory health problems such as airway inflammation, bronchitis and asthma. Also, a link with cardiovascular effects, cancer and total mortality has been suggested. To prevent adverse health effects, a 1-hour mean exposure threshold of about 100 ppb and an annual mean of 20-50 ppb have been set in the United States and European Union. However, NO2 concentrations show a strong seasonal dependence and annual thresholds are frequently exceeded in several European cities. Therefore, widespread monitoring of NO2 with low-cost sensors is needed. Sensors based on chemoresistive metal oxide nanoparticles are promising due to their high miniaturization potential, low power consumption and inexpensiveness. However, they usually lack selectivity to accurately detect such low NO2 concentrations.
Methodology	Flame spray pyrolysis (FSP) allows easy control over material composition and morphology of nanoparticles to tailor gas sensing properties to a target analyte. Here, we produced a highly selective and sensitive NO2 gas sensor by FSP. Thereby, a liquid organometallic precursor is dispersed by an oxygen flow into fine droplets and ignited using a premixed methane/oxygen flame. Generated nanoparticles were directly deposited onto water-cooled sensor substrates featuring interdigitated electrodes. For the evaluation of the sensor performance, the sensors were installed in a sensor chamber. Calibrated gas standards were used for characterization. Upon analyte exposure, the film resistance changes, as monitored by a multimeter, and results in a sensor response proportional to the analyte concentration.
Results & Conclusions	The optimized sensors were tested to NO2 exposure and relevant interfering compounds at 50% relative humidity. NO2 was detected accurately down to 5 ppb with high signal-to-noise ratio (>10). Furthermore, the sensor exhibited excellent selectivity (>100) over acetone, ethanol, CO and ammonia. As a result, the investigated sensing material shows great promise for integration into low power and autonomous NO2 monitors.

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Coauthors	Lukas Durdina; Curdin Spirig; Jacinta Edebeli; Michel Guillaume
Publication title	Do unregulated aircraft engines really emit much higher non-volatile PM mass and number than regulated ones?
Publication type	Poster
Introduction & Background	The new non-volatile particulate matter standard (nvPM), which was developed within the ICAO Committee on Aviation Environmental Protection (CAEP) is coming into place per first of January 2020. By then, all in-production engines are required to fulfill this standard, defined by new nvPM mass limits. It is planned that by 2023, the standard gets even more strict by limiting the maximum nvPM mass and number emission index (EI). Yet, this new standard only needs to be complied with for relatively large engines (>26.7 kN of thrust). Smaller engines, like the ones used on business jets, must comply with a much less stringent emission regulation. Although business aviation only uses 2% of the world's aviation fuel, the relatively short flight legs lead to an above average local influence of the air quality compared to larger aircraft. Additionally, a recent measurement campaign of a Swiss Air Force business jet showed far higher nvPM EIs during most of the landing-and-take-off-cycle than widely used large engines which had been measured using the same sampling system (Durdina et al., 2018, Non-volatile PM Emissions of a Business Jet Aircraft: Ground Measurements and Cruise Estimates, http://nanoparticles.ch/archive/2018_Durdina_PR.pdf). To solidify our hypothesis of high nvPM EI of unregulated engines, another business aircraft engine type was measured during a recent field campaign.
Methodology	During a three-day-long field campaign, the Swiss Mobile Aircraft Emission Measurement System (SMARTEMIS) was used. SMARTEMIS consists of a gas-phase measurement instrumentation, able to determine the CO2, CO, NOx, O2, SO2 and unburned hydrocarbons concentration, and a nvPM measurement instrumentation, able to determine nvPM mass, size and number. A cruciform probe with 12 sampling ports was used, mounted on a heavy-duty forklift, right behind the engine of the business jet. We calculated nvPM emissions for the landing and take-off cycle and estimated emissions at cruising altitude using an engine performance model.
Results & Conclusions	The measurements could confirm that small, unregulated engines are indeed emitting much higher nvPM number and mass per unit of fuel than large, regulated airliner engines. These results call for an improvement of the situation by employing state-of-the art combustors in small jet engines. A future regulation for engines below 26.7 kN thrust may be beneficial to this process.

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Publication title	Investigation of the correlation between a prototype Advanced Halfmini DMA and a commercial SMPS for combustion-generated solid sub-23 nm particles measurement
Publication type	Poster
Introduction & Background	Modern diesel and gasoline (G-DI engine) vehicles may emit nucleation mode particles in the sub-23nm region, either under special conditions or as part of their normally emitted size distribution, respectively (Giechaskiel and Martini, 2014). Moreover, solid sub-23nm particles are also reported to be emitted by CNG and LPG engines (Alanen et al., 2005). These findings led to the investigation of measurement approaches for reliable detection of sub-23nm particle emissions (Melas et. al, 2019). Hot emission measurement with the Advanced HalfminiDMA (SEADM S.L.) coupled with a sampling system of minimum requirements was also proposed for accurate detection of solid sub-23nm particles (Baltzopoulou et al., 2019). The Advanced Halfmini-DMA was initially developed by Fernadez de la Mora & Kozlowski (2013) for high resolution measurement of particles in the size range 1-15 nm, at ambient temperature. After recent modifications (Fernadez de la Mora, 2017; Amo M. et al., 2017; Amo M. et al, 2018) the system is capable of exhaust aerosol measurements with an extended particle size range up to 30 nm, at high temperatures up to 200°C. In this modified system, particle charging occurs by a Secondary Electrospray Ionisation (SESI) charger which is adopted for charging hot (50–200°C) aerosols. However, understanding and determining the charging efficiency of such a unipolar charger is a challenging task. In this study, we performed a preliminary experimental correlation of the prototype Advanced Halfmini-DMA ions concentration signal to SMPS particle concentration using aerosols of different concentrations, generated either by a standard propane burner or a diesel engine.
Methodology	Particle nucleation mode of different concentration levels was measured by the Advanced Halfmini-DMA in tandem with a reference SMPS system (TSI, NanoDMA 3085, CPC 3776) in order to investigate their correlation. The generation of solid particles was performed with a CAST burner and with a single cylinder, four-stroke, 5 kW, air-cooled direct injection diesel engine. CAST operated at different dilution ratios (DR=20 and 70) using a rotary diluter or with no dilution (raw exhaust measurement). In the case of the diesel engine, we used two different fuel mixtures that resulted in the production of solid nucleation. Under these conditions, the diesel engine generated a bimodal distribution including nucleation particles in the range of 7 – 30 nm and in concentrations varying from 3*10^5 to 2*10^7 particles/cm^3. For evaluation purposes, the produced correlation was implemented in a measurement of exhaust emitted by a last-generation, four-stroke, GDI engine in comparison to the DMS500 (Cambustion) measurement.
Results & Conclusions	Five sets of experimental data were obtained correlating prototype Advanced Halfmini-DMA ions concentration to SMPS particle

	concentration with a size-dependent exponential relation. The overall correlation is considered good for the studied range of particle concentration values that is of interest for the engine exhaust measurements. Such correlation was used in GDI sub-30nm particle measurement to correct prototype system's raw signalto particle number concentration with acceptable agreement with commercial DMS500. Acknowledgement: This work was supported by the Horizon 2020 E.U. Framework Programme, through the SUREAL-23 project (Grant Agreement 724136).

	Barrios Carmen
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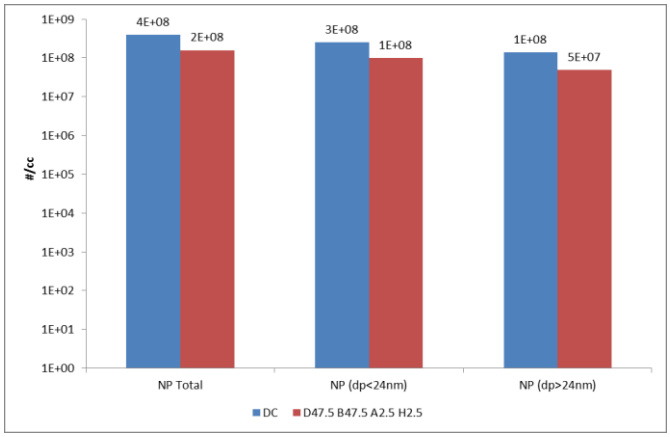
Coauthors	Jesus Casanova; Daniel Neira; Iratxe Galarraga; Paloma Álvarez
Publication title	Influence of the use of oxygenated additives on the particle emissions of a Euro 3 urban bus from the current fleet in the city of Seville
Publication type	Poster
Introduction & Background	The transport sector is one of the main contributors to pollutant emissions into the atmosphere. Emissions from vehicles damage urban air quality and cause health problems for people. Both public administrations and research organizations are making big efforts to reduce pollutant emissions and an alternative to solve it is the use of unconventional fuels that reduce dependence on fossil fuels and also reduce emissions. The vehicle emission group (GEV) of the Center for Energy, Environmental and Technological Research (CIEMAT) has been testing different types of fuels in different engines for years, including biofuels of vegetable origin and those from waste oils. Currently, among their projects, they are working on the LIFE + Bioseville project, which aims to recover fried oils to produce high-quality biodiesel and oxygenated additives from waste glycerin from biodiesel manufacturing. The aim of this work is to make a comparative analysis of gaseous emissions (CO2, NOx and HC) and nanoparticle emission in number and size distribution of a bus engine (Euro 3) with different proportion of conventional diesel, biodiesel, waste cooking oil and oxygenated additives from glycerin (diacetyl glycol) (47.5% Conventional Diesel, 47.5% Biodiesel, 2.5% additives and 2.5% heptane). The bus used is part of the fleet that circulates daily in the city of Seville as part of the service provided by the Urban Transport Company of Seville (TUSSAM) and has been driven through the city during the month of January fulfilling the busiest bus lines in the city.
Methodology	The measures of polluting emissions from the bus were made in an urban bus of the real bus fleet, an IVECO CityClass E3 bus. 3 lines were covered. The three lines have been selected among those with the highest number of register users. To ensure the validity of the data, 3 repetitions of each line have been made. The measuring equipments installed in the bus were: an OBS2200 system from HORIBA, an EEPS from TSI and a rotatory disk dilutor from Matters Engineering. The bus circulated without passengers, reason why the weight of the passage was simulated with sandbags that added 1000 kg (Figure 1). In addition, in order to avoid the influence of the driver on emissions, the same driver was always used.
Results & Conclusions	Among the most relevant results obtained with this study in an urban bus (Euro 3) is the influence the addition of 2.5% acetyl glycol and 2.5% heptane to the mixture of 47.5% conventional diesel (DC) and 47.5% biodiesel (B) has on the emission of nanometric particles. It was concluded that on average the total number of nanometric particles emitted by the engine was reduced when using this blend a 60.19% (1.58E8 #/cc) when compared with those emitted with conventional diesel (DC) as fuel (3.96E8). On the other hand, the size distribution showed important changes. The use of oxygenated additive promoted the appearance of a smaller number of particles in the accumulation mode (dp>24 nm), with an average number of 4.92E7 #/cc, while the number of particles in the accumulation mode of experiments carried out with diesel was 1.37E8 #/cc (Figure 2).

Images	
Caption Figure 1:	 Assembly inside the bus
Caption Figure 2:	 Comparisons between different fuels

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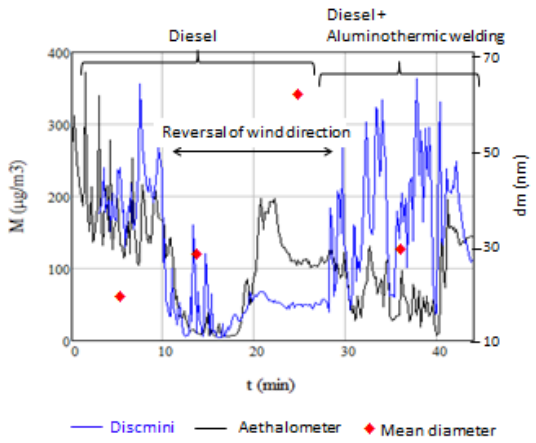
Publication title	Measurement of ultrafine particles during repair works in railway tunnels
Publication type	Poster
Introduction & Background	Measurements were carried out in a railway tunnel during rail replacement works. Cutting, grinding and aluminothermic welding operations were carried out. The tools are powered by diesel electric generators without diesel particle filters (DPF). The particulate pollutants were composed of ultrafine particles generated by these different sources: carbon and metallic particles. A set of measurements of the characteristics of the ultrafine aerosol in real time was implemented to evaluate the exposure of the workers.
Methodology	Measurements were made using three direct reading devices. A Discmini (Testo®) allowing the measurement of the particle number concentration whose size is between 10 and 300 nm as well as the average particle diameter. The mass concentration of the particles from 10 to 300 nm was determined from the Discmini data, namely the number concentration and the average diameter. A portable aethalometer (AE51, Aethlabs®) for the determination of the mass concentration of black carbon (BC) particles. An analyzer (Nanoscan, TSI®) allowing the measurement of particle size distribution in number (between 10 and 300 nm). A 100-fold dilution of the aerosol (Dil 550, Palas®) was performed for the Nanoscan and Discmini analyzers. These real-time measurements were completed by measuring the concentrations of EC/OC by thermo optical method (Sunset Laboratory®).
Results & Conclusions	The measurements clearly show different phases depending on the ventilation conditions inside the tunnel and the activity of the different polluting sources. To the carbonaceous particles produced by diesel engines are added the metal particles generated during the cutting and especially welding works. The particles which are of the form of aggregates of very small size (107 part./cm3). The mass concentration deduced from Discmini can be compared to the black carbon concentration given by the aethalometer in order to establish the specific contribution of the metallic particles to the pollution. An example of concentrations profile is given in Fig.1. The EC concentrations are in good agreement with the BC concentration determined from the micro-aethalometer. The measuring system used allows a fairly complete characterization in real-time of the ultrafine aerosol present in these workplaces: mass concentration of total particles and black carbon, number concentration and particle size distribution. If the workers involved in cutting and welding operations are equipped with respiratory protection (powered air respirators with hood), the other people working nearby are highly exposed and protective solutions should be considered: DPF installation on electric generators, welding fumes extraction by mobile unit, generalization of individual respiratory protection.
Images	

Caption Figure 1:	 Typical mass concentration profiles obtained from Discmini and micro-aethalometer, for different working phases and ventilation conditions inside the tunnel.

	Bennett Anthony
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Coauthors	Emre Cenker; William L Roberts
Publication title	Thermophoretic sampling of a pressurized non-premixed ethylene/nitrogen laminar co-flow flame
Publication type	Poster
Introduction & Background	Soot is formed through the incomplete combustion of hydrocarbons. Increasingly stringent regulations on combustion emissions are driving the effort of fundamentally understanding the soot formation process, especially at pressurized conditions relevant to modern combustion devices. To develop and validate soot formation simulations, canonical flames with well-defined boundary and flow conditions are typically used.
Methodology	To increase our understanding of the effects of pressure on soot formation we used a non-premixed laminar coflow jet flame in this study. Ethylene diluted with nitrogen was used for the fuel with a constant fuel mass flux, and air was used in the coflow. A stable flame of approximately 20 mm in height as measured by the natural luminosity was formed. Soot was thermophoretically sampled onto transmission electron microscopy (TEM) grids at pressures between 2 and 16 bar at a sampling height above the burner (HAB) of 5 mm, 10 mm, and 15 mm. Images were taken with a transmission electron microscope, and primary particle size (dp) values were measured manually. After average dp values were found, fractal prefactors and fractal dimensions were found. This was done by fitting a line to a log-log plot of N vs L/dp, where N is the number of primary particles in the aggregate, L is the length of the aggregate, and dp is the average diameter of the aggregates.
Results & Conclusions	Primary particle sizes were found to increase by over 2 fold at 5 mm HAB from an average dp of 28 nm at 8 bar up to an average dp of 64 nm at 16 bar. At 10 mm HAB, average dp increased from 20 nm at 4 bar, up to an average dp of 69 nm at 16 bar. At 15 mm HAB, average dp was found to be less sensitive to pressure than at lower HABs, increasing from 15 nm at 2 bar, up to 33 nm at 16 bar. Fractal prefactor and fractal exponent did not show any apparent trends with pressure. The fractal prefactor varied between 1.94 and 2.33 and the fractal exponent varied between 1.67 and 1.88.

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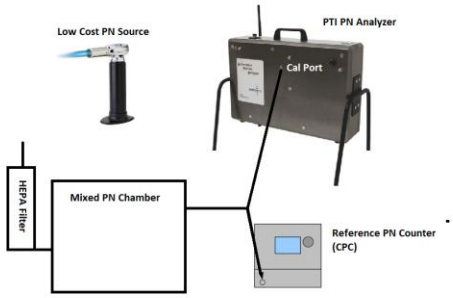
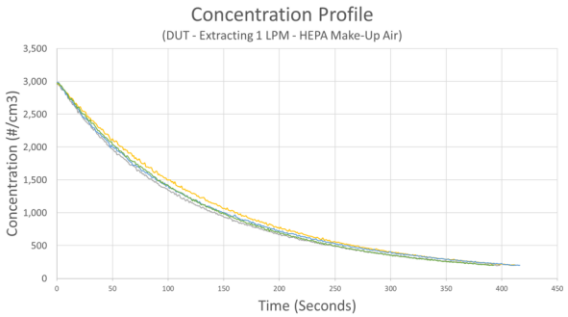
Publication title	Development of a Portable Particle Number Field Calibration Methodology / Instrument for the anticipated EU PN Periodic Technical Inspection regulations
Publication type	Poster
Introduction & Background	With the anticipated widespread introduction of a light-duty Particle Number (PN) Periodic Technical Inspection program in Europe in the near future, Sensors Inc. has been developing a low cost, easy to use, and quick field calibration Methodology / Instrument.The unique requirements of operating in the demanding PTI environment require the complexities of performing such measurements to be carried out whilst maintaining meteorology traceability in the field. This presentation will cover the development and testing of a robust, easy to use calibration methodology / instrument for field calibration of the many thousands of PTI PN Instruments anticipated to be deployed throughout Europe into garages and PTI test-lanes. In particular, metrology studies examining the complexity of calibration in the framework of the resulting measurement uncertainties has been used to provide a potential simplified lower-cost calibration field-based procedure.
Methodology	The proposed methodology for field-based linearity and span of the PN PTI devices can be completed in less than 5 minutes and utilizes ready-available components (PN source) and well established exponential decay curves (analogous to air exchange tracer gas procedures) to calibrate the field instruments. Particles are introduced into a continually stirred tank using readily available propane (eg kitchen torch) and allowed to mix. The fully mixed particles are then extracted by the PN device under test and a reference PN counter. During this process, HEPA filtered make-up air is drawn into the tank providing a smooth (exponential decay) of PN over a few minutes. The data provides linearity, span and zero validation.
Results & Conclusions	The results that will be presented show that the methodology is robust, simple to use and moreover is expected to meet the market cost concerns by being very affordable. The study examines amongst other things repeatability, reproducability, aerosol coagulation rates and solid / semi-volatile artifacts mitigation.
Images	

Caption Figure 1:	 Simplified Calibration Hardware Setup
Caption Figure 2:	 Concentration Decay Profile

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Coauthors	Natalia Fonseca; Nuria Flores; Fredy A. Rosero
Publication title	Experience using a diffusion charging particle counter in a Euro V diesel city bus in Madrid. Influence of the transient conditions on PN emission factors.
Publication type	Poster
Introduction & Background	In large cities as Madrid, the environmental impact of particulate matter smaller than 2.5 microns are significant. The city buses fleet in Madrid still has a significant number of Euro V diesel buses which contribute in an unknown percentage to the total amount of PN in the atmosphere. In order to assess the influence of the driving pattern of a diesel city bus along a real city bus line in the Particle Number (PN) emissions, a Diffusion Charging (DC) particle counter has been coupled to the exhaust system in series with a portable Emissions Measurement System. With this emissions measurement system, the real life PN emissions have been measured in a Euro V diesel bus in a city line of Madrid. The objective was by one side to validate the DC particle counter Pegasor for real driving emissions measurement and by the other to understand the influence of the driving pattern of city buses in a large cities as Madrid, in which the slopes and the positive acceleration from bus stops play a significant role in the transient and averaged emissions. The results were obtained in terms of PN emissions as function of average speed, positive acceleration, slope of the street and load of the bus in other to establish correlations and to propose specific driving patterns for particle emissions reduction
Methodology	A Horiba OBS 2200 PEMS and a Pegasor have been coupled to the exhaust system of an IVECO urban bus. Some operative conditions of the engine were recorded from the OBD system. A laptop was used to record in real time the PEMS results, the OBD data and the PN from the Pegasor. The bus was driven by the real line 74 of Madrid, following the actual bus stops in three conditions: empty, 1500 kg and 4000 kg of payload. The PN have been measured in #/cm3 and passed to #/km by means of the instant exhaust flow measured by the PEMS and the bus speed was recorded from the OBD. Each test was repeated three times in each sense of the route of the line 74 in order to minimise the influence of the local traffic behaviour. The data obtained were averaged and treated to obtain the relations between instantaneous transient conditions of the driving and the PN and also with some other emissions and parameters.
Results & Conclusions	The results of PN, bus speed and slope for each test are presented as PN emissions as function of time and distance travelled in order to identify driving conditions of higher PN emissions. The main conclusions are that the Pegasor is a very simple and low-cost instrument for PN measurement in real driving conditions with on-board instrumentation, although it need a continuous compressed air supply. Other conclusions about the PN emissions during idle and small bus seed as a part of the averaged PN per km are presented. Other conclusions are that the payload of the bus and the positive slope of the street are the main influence on the total and averaged Particle Number in a city bus in Madrid
Images	

Caption Figure 1:	 Horiba flowmeter and Pegasor attached to the city bus exhaust duct
Caption Figure 2:	 Instrumentation controls and data recording inside the bus

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Publication title	Respiratory Mutagenicity and Inflammation Induced by Size-segregation Ambient Particles in Mice: Do ultrafine particles cause greater toxicity?
Publication type	Poster
Introduction & Background	The health effects of ambient particulate matter (PM) have been demonstrated. However, it is unclear about the health effect induced by ultrafine particles (PM0.1). The aim of this study was to investigate the toxicity of PM0.1 and compare its toxicity to the larger particles.
Methodology	We used MOUDI to collect ambient particles in the winter and summer. Components of PM were analyzed. The collected particles were grouped into PM10-1, PM1-0.1, and PM0.1. Each BALB/c male mouse was then administered with 75 μg of particles by intratracheal instillation. The animals were sacrificed after 24 hours, then blood and bronchoalveolar lavage fluid (BALF) were collected. Neutrophil, IL-6 and TNF-a in the BALF, and level of 8-OHdG in the lung, and DNA strand break in the lung and the peripheral blood were determined. DNA strand break was determined by comet assay.
Results & Conclusions	The composition analysis revealed that organic carbon (OC) accounted for 16.25%, followed by sulfate ions with 12.53% for PM10-1. While sulfate ions was most abundant (31.42%) in PM1-0.1, followed by OC (20.3%). In PM0.1, OC accounted for 18.7%, followed by sulfate ions of 5.95%. Polyaromatic hydrocarbon (PAH) was higher in PM0.1 (0.349 ng/ug PM), followed by PM1-0.1 and PM10-1 (0.052, 0.024 ng/ug PM) in the winter time. While PM0.1 and PM1-0.1 were higher in the summer (0.148 and 0.142 ng/ug PM) followed by PM10-1 (0.024 ng/ug PM) Neutrophil was higher in PM1-0.1 and PM0.1 group as compared to the control group in summer, while three PM groups had higher neutrophils in the winter. The 8-OHdG in PM10-1, PM1-0.1, PM0.1 was significantly higher than the control group in winter. However, the similar findings were not observed in summer. DNA strand breaks increased after the treatment of PM10-1 and PM0.1 in both seasons. However, PM0.1 did not induce higher toxicity as compared to PM10-1 and PM1-0.1 in all markers. Further analysis showed levels of PAH were associated with neutrophil, 8-OHdG and DNA strand break. The results showed that ultrafine particles could induce lung inflammation, oxidative stress, and DNA damage. However, ultrafine particles did not cause greater toxicity as compared to fine and coarse particles. Our study also suggests that PAH is an important components for PM toxicity. Further studies are needed to elucidate the role of other components on PM toxicity.

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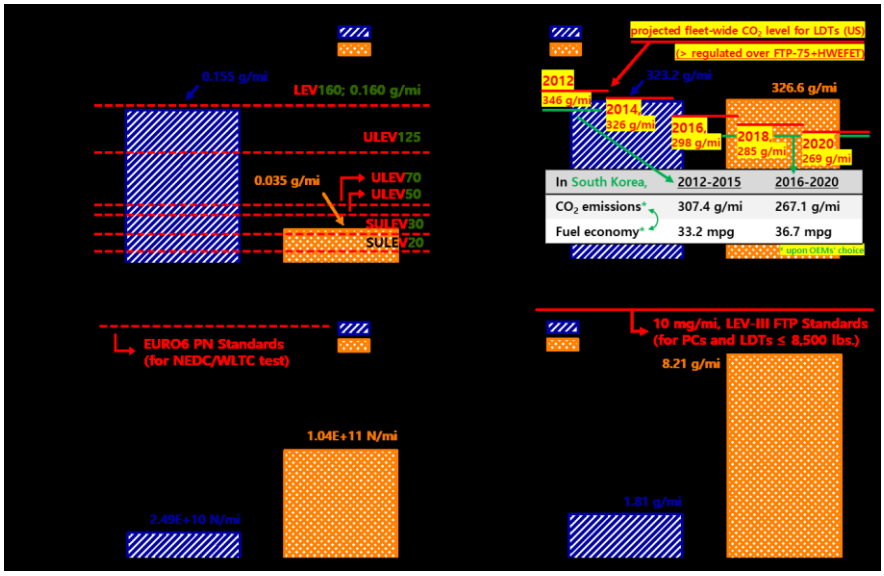
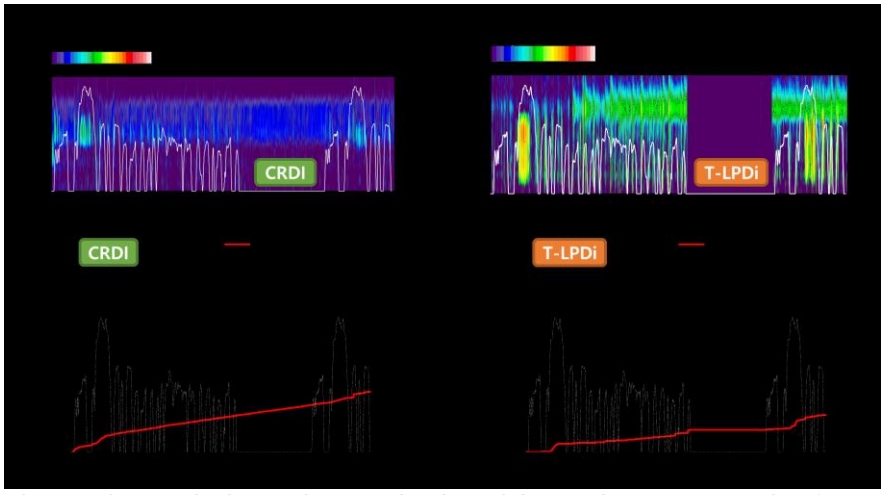
Publication title	Comparative study on regulated emissions and size-resolved particle emissions from light-duty truck equipped with common rail direct injection (CRDI) diesel and turbocharged LPG direct injection (T-LPDi) engine under various vehicle test conditions.
Publication type	Poster
Introduction & Background	Light-duty truck (LDT) is one of the best sellers globally and its usage is quite severe than passenger cars. Therefore, environmental effect of LDTs is important but not fully recognized. In Republic of Korea, 1-ton truck is a steady seller and also at the top of monthly sales list except for new cars for recent several months. Because of the usage and user of this LDT, a diesel engine with turbocharged common rail direct injection (CRDI) system have been mainly used to meet the requirement of users, higher torque performance from low engine speed. However, adoption of real driving emission (RDE) test procedure become inevitable, which results in compulsory complicate aftertreatment system (e.g. selective catalytic reduction; SCR, gasoline particulate filter; GPF). This is unconformable measure for the LDT, so that cost effective and ecofriendly engine technology should be developed. In this study, a newly developed turbocharged liquefied petroleum gas (LPG) direct injection (T-LPDi) engine was used to deal with this problem. This approach was inspired by previous study, a stoichiometric LPDi scheme to reduce particle emissions from a gasoline direct injection (GDI) vehicle. With a turbocharger, LPDi engine can generate more torque under low engine speed operation, such as diesel engine, while exhaust emissions will be reduced due to the advantageous fuel properties of LPG fuel. This study aims to investigate the exhaust emission characteristics of diesel (Euro 6b compliant with lean NOx trap; LNT) and T-LPDi 1-ton trucks and discuss their environmental impact. Through this, abatement capability in CO2, NOx, and size-resolved particle emissions from LDT can be quantified and it can broaden understanding on advanced LPG fueled SI engine with state-of-the-art combustion technology.
Methodology	In this study, two 1-ton trucks were used, which are equipped with turbocharged CRDI diesel and T-LPDi engines respectively. The experimental setup with these vehicles and apparatus is shown in Figure 1. For vehicular emission test, a 48-inch single roller chassis dynamometer (AVL, M4500) was used. Regulated emissions were measured by an exhaust gas analyzer (AVL, AMA), a constant-volume sampler (AVL, CVS i60 LD), and a full-flow exhaust gas dilution tunnel (AVL, PPS i60 SD). Size-resolved particle emissions were investigated via a differential mobility spectrometer (Cambustion, DMS500). A sample line of the DMS500 was installed at the downstream of the tailpipe of test vehicles. The measurement system follows quite similar procedure to the particle measurement program (PMP). Sampled particles are classified by a cyclone at the dilution device, which is connected directly with heated sample line. Then, under 1μm size of nano-particles pass through two-stage dilution system with pressurized (~ 3 bar) air, which is supplied from outside of the device and filtered with a high efficiency particulate air (HEPA) filter. Then, an electric charger unit charges classified particles as positive. Thereby they move forward a detection part composed of 23 rings

	in series, which have negative electric charge. From 5 nm to 1 μm, the DMS500 can measure particle number concentration by diameter size using the balance of inertia and electrostatic force of the particles.
Results & Conclusions	During FTP-75 mode test, Regulated emissions (NMOG+NOx, CO2, and PM) and size-resolved particle number emissions were measured and summarized in figure 1 and 2. The CRDI diesel vehicle is equipped with LNT+DPF system which meets Euro-6 emission regulation over NEDC test. The LPG vehicle has a stringent target legislation, which is US's LEV-III SULEV standards. A previous generation, LPG liquid phase injection (LPi) vehicle, was LEV-II ULEV compliant vehicle and the next one used the same specification of TWC system but equipped with new T-LPDi engine. NMOG+NOx emissions were 0.155 g/mi and 0.035 g/mi for CRDI and T-LPDi respectively, which shows clear difference from combustion physics and aftertreatment system. There was a comparable result on CO2 emissions, while particle emission results represented that relatively high concentration and mass emitted from T-LPDi vehicle. As shown in upper side of Figure 2, real-time particle number emissions by size explain the reason why the PN and PM emissions from T-LPDi were higher than that from CRDI. Around 100 nm of peak point, accumulation mode particles steadily discharged from both vehicles, as under 100 nm of nucleation mode particles were increased with harsh acceleration in only T-LPDi case. These tendencies would resulted from whether the vehicle has a particulate filter or not. Through this study, the results showed that T-LPDi application on LDT can be a good alternative of conventional diesel system in terms of CO2 emissions and NOx emissions. Also, the superior particle emission abatement capability of it would give flexibility on engineers who consider a filtration system for PN reduction under RDE condition, though there are still further works to improve the systems' overall efficiency. [Acknowledgement] This study was supported by the BK21 plus program (21A20131712520) through the National Research Foundation (NRF) funded by the Ministry of Education of Korea and CEFV (Center for Environmentally Friendly Vehicle) as Global-Top Project of KMOE (Ministry of Environment, Korea) (2016002070006). We are also grateful to the Hyundai Motor Company for their technical assistance on the development of T-LPDi engine.
Images	

Caption Figure 1:	 Summarized regulated and particle emissions comparison result.
Caption Figure 2:	 Time series analysis on size-resolved particle number concentration from the LDTs (for FTP-75).

	Ciajolo Anna
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Coauthors	anna ciajolo
Publication title	The common thread between fuel, hydrocarbon, soot structure and its oxidation reactivity
Publication type	Poster
Introduction & Background	With the development of powerful diagnostics for deriving nanostructural parameters of carbons by both spectroscopic tools and imaging at nanometric level, it has been shown that soot nanostructure depends on its formation chemistry, i.e. on the hydrocarbon environment in which it is formed (1,2). Beside to combustion parameters as C/O feed ratio and temperature, the hydrocarbon environment is idetermined by the fuel molecule identity, As soot structure also affects soot oxidation reactivity in this work the effect of fuel on soot nanostructure and then on soot reactivity has been studied in flames of prototypical hydrocarbon fuels as methane, ethylene and benzene.
Methodology	Soot was sampled downstream of methane, ethylene and benzene premixed flames burning in similar conditions.. Soot oxidation was studied in a thermogravimetric apparatus operating in air environment up to 800°C, whereas spectroscopic tools as FTIR and Raman along with transmission electron microscopy (TEM) and elemental analysis was performed on soot sampled.
Results & Conclusions	Various structural parameters of methane ehylene and benzene soot, as the average crystalline length, the hydrogen content and soot particle size, have been correlated with thermogravimetric analysis (TGA) data carried out in air flow. To investigate the structural factors affecting the different oxidation behaviors, surface functionalities in terms of hydrogen content and quality have been analyzed by FT-IR. Moreover, Raman spectroscopy was used at different excitation wavelengths to analyze soot structure and determine the aromatic layer length. Methane soot showed to be the most reactive among the samples. Benzene soot appeared the more resistant to oxidation in spite of the small size of benzene soot particles as evaluated by TEM analysis and the consequent higher surface area. Consistently with the lower oxidation reactivity, benzene soot presents a lower hydrogen content and higher graphitic order within the particles nanostructure. Conversely, methane soot is characterized by the lower aromatic cluster size and the higher hydrogen content. Overall, these characteristics correspond also to a thicker amorphous shell observed by TEM of benzene soot particles which is expected to cause the lower reactivity to oxidation of benzene soot. Ethylene and soot presented a mixed amorphous/graphitic character with the predominance of amoprhous in th case of methane, These data demonstrate that the internal structure of soot particles in terms of layer length and amorphous character are more important than particle size for determining soot oxidation reactivity.

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Coauthors	Joel C. Corbin; Amrith Senaratne; Jason Olfert; Greg Smallwood; Stephanie Gagné; Fengshan Liu; Prem Lobo
Publication title	Characterization of the Argonaut miniature inverted soot generator with various fuel mixtures
Publication type	Poster
Introduction & Background	The graphitic, strongly light-absorbing carbonaceous particles generated by incomplete combustion (soot) play a major role in air pollution toxicity and the Earth's radiative budget. As these effects are dependent on particle size and composition, it is essential that laboratory studies are performed on soot which accurately represents real-world sources. The Argonaut miniature inverted soot generator (MISG) employs a simple design to produce soot which is similar to real-world soot in terms of size and degree of graphitization, with a mode mobility diameter of ~150 nm achieved when using ethylene (Kazemimanesh et al., 2018) or propane (Moallemi et al., 2019) in its two-flow, air–fuel diffusion flame. These particles are useful surrogates of the soot produced by internal combustion engines or biomass combustion. However, they are substantially larger than the very small (~50 nm) and highly graphitic particles observed in the exhaust of typical aircraft engines (Vander Wal et al., 2014; Liati et al., 2014).
Methodology	In this work, we therefore explore the ability of the MISG to produce small (
Results & Conclusions	We evaluated the degree of graphitization by real-time measurements of the mass absorption cross-section (MAC) of our samples using the CPMA-Electrometer Reference Mass System (CERMS) and, for certain conditions, verified our interpretations using filter-based measurements of its elemental carbon (EC) content.

	Corbin Joel
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Coauthors	Joel C. Corbin; Martin Gysel
Publication title	Detection of tar brown carbon with the single particle soot photometer (SP2)
Publication type	Poster
Introduction & Background	Atmospheric light-absorbing carbon (LAC) in particulate matter (PM) plays a substantial role in the radiative balance of the earth both directly and by influencing cloud properties (IPCC, 2013). While soot black carbon (soot BC) is the best-recognized form of LAC (Bond et al., 2013), increasing attention has recently been paid to the so-called ``brown carbon'' and ``tar balls'' which possess substantially different physical properties than BC. The term ``brown carbon'' is canonically used to refer to the collection of substantially light-absorbing organic molecules found in PM, while the term ``tar balls'' refers to the insoluble amorphous-carbon spheres which may be produced by the pyrolysis of high-molecular-weight fuels such as biomass (Toth et al., 2014) or heavy fuel oil (Corbin et al., 2018). Here we will refer to these two sub-types of brown carbon as ``soluble brown carbon'' (soluble brC) and ``tar brC'' following Corbin et al. (2018). Both forms of brC may comprise a large fraction of the light absorption of atmospherically-relevant aerosols such as wildfire smoke and marine-engine exhaust. The SP2 is a common technique for measuring soot BC which may be cross-sensitive to tar brC, a relationship which has not yet been explored.
Methodology	We explore the possibility that a detailed analysis of these time-resolved signals allows the detection of tar~brC particles by SP2 in terms of their (predicted) anomalous scattering signals.
Results & Conclusions	We find that tar brC results in unique signals due to a combination of complete or partial evaporation in the SP2 laser with no or very little incandescence. At incandescence, the scattering cross-section of tar particles was up to a factor of two greater than that of soot black carbon (soot BC), for similar incandescence signals. This enhanced light scattering is interpreted as due to the less graphitic nature of tar brC compared to soot BC, such that a substantial fraction of the tar particle does not absorb enough 1064\,nm radiation to be heated to incandescence. The fraction of the tar particle which does incandesce was likely thermally annealed during laser heating. Since incandescence signals in the SP2, normally reported as ``refractory black carbon'' (rBC), are typically used to measure the soot-BC mass contained within a given particle, incandescence signals from tar particles represent a source of bias in SP2 measurements. We found that this bias is overall negligibly small in our marine-engine data set, even though the mass of tar brC was threefold greater than that of soot BC. These results indicate that laser-induced incandescence, as implemented in the SP2, is the only BC measurement technique which can quantify soot BC concentrations separately from tar, while also potentially providing real-time evidence for the presence of tar. In contrast, BC measurement techniques based on thermal--optical (``EC'') and absorption (``eBC'') measurements cannot provide such distinctions. We predict that that the more- and less-graphitized tar samples reported in the literature from different sources may show stronger and weaker SP2 responses, respectively.

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Publication title	PN Emissions of Passengers Cars – Potentials of GPF's
Publication type	Poster
Introduction & Background	Reduction of PN-emissions from traffic and from IC-engines is a continuous and important objective. The merits of DPF are mostly neglected in the public information. The potentials and necessities of further introduction of GPF are not enough considered. In the present work, we show the potential of PN-reduction of different car concepts as demonstrated by the AFHB research activities.
Methodology	Emissions of several passenger cars were investigated on chassis dynamometer in dynamic driving cycles and in steady state operation. The PN-emissions were measured according to the legal requirement with CPC in CVS-tunnel and for the research purposes with SMPS at tailpipe.
Results & Conclusions	The important results are: • The modern SI-vehicles with MPI can emit a considerable amount of PN and PM. In an extreme case, the PN-emission was in the range of Diesel car (without DPF). • With the GPF's with better filtration quality, it is possible to lower the emissions below the actual European limit value of 6.0 x 1011#/km. • The PN-filtration efficiency of actually used GPF's is significantly lower than the efficiency of right-quality DPF's. • The improvement of GPF filtration efficiency by coating alone is not sufficient. • The variant Diesel + DPF offers the highest filtration quality, the lowest PN-emissions and it is considered by the authors as a recommendable bench-mark. • A modern CNG car would still have remarkable PN-reduction potentials with a right-quality GPF.

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Publication title	Considerations of Periodical Technical Inspection of Vehicles with deNOx Systems
Publication type	Poster
Introduction & Background	An independent periodical technical inspection (PTI) of vehicles is proposed in the last time as a better prevention against increased emissions of the fleet. Several projects focused on the Diesel vehicles (HD & LD) and on the functionality of the exhaust aftertreatment systems as a key element for lowering emissions of a vehicle or machine.
Methodology	The present paper summarizes the results obtained on 3 modern passenger cars Euro 6b (with EGR, DOC, DPF & SCR) during load jumps, representing the heat-up or cool-down behaviour of the exhaust system. The portable devices for PTI were tested together with the stationary measuring systems of the engine laboratory. In the second part of the report, the present knowledge and proposals of supplementary test procedures (like IUC or PTI) were shortly described.
Results & Conclusions	It can be stated that the efficiency of the SCR-systems in a short PTI test is visible, and it is possible to quantify it in the positive or negative load jump, if a longer driving period at the constant OP (10 to 15 minutes) is realized in order to attain the stabilization of the system. For that a chassis dynamometer is recommended. A simple “5 minutes” test of the functionality of a deNOx system is not possible. On the contrary, the testing of DPF quality can be easily and quickly performed by means of a PN-measurement at vehicle standstill and it became already a legal reality in some countries.

	Decrue Fabienne
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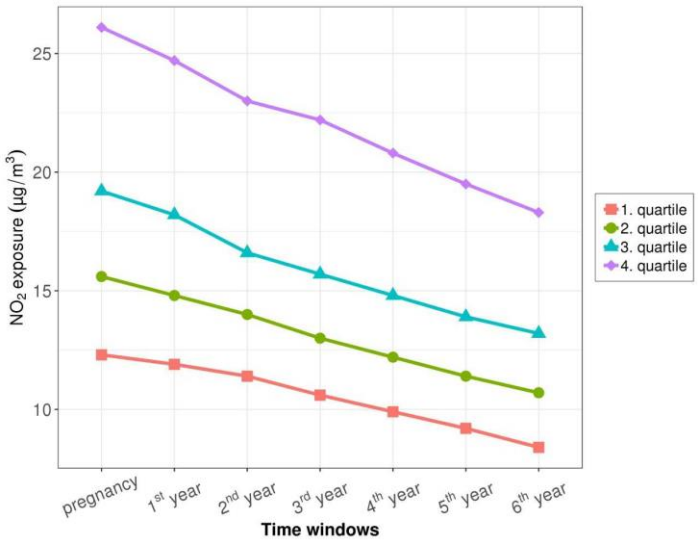
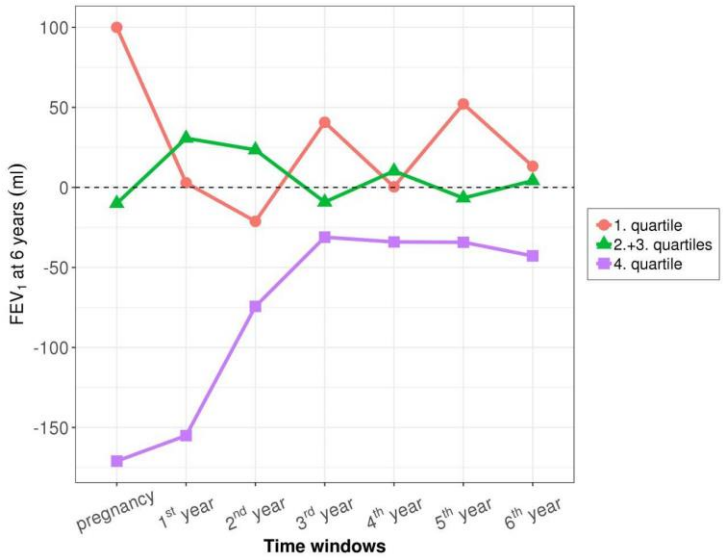
Coauthors	Jakob Usemann; Insa Korten; Elena Proietti; Olga Gorlanova; Danielle Vienneau; Oliver Fuchs; Philipp Latzin; Martin Röösli; Urs Frey
Publication title	Exposure to moderate air pollution and associations with lung function at school-age: a birth cohort study
Publication type	Poster
Introduction & Background	Introduction: Adverse effects of higher air pollution levels before and after birth on subsequent lung function are often reported. We assessed whether low-to-moderate air pollution levels during preschool-age impact upon lung function at school-age.
Methodology	Methods: In a prospective birth cohort of 304 healthy infants, 232 (79%) completed lung function at follow-up at six years. Using spatial-temporal models, levels of individual air pollution (nitrogen dioxide (NO2) and ozone (O3), particulate matter with a diameter
Results & Conclusions	Results: Mean NO2 level from birth until follow-up was [mean (range)] [11.8 (4.9 to 35.9 µg/m3)], which is almost 4-times lower than the WHO suggested limit of 40 µg/m3. In the whole population, increased air pollution levels were associated with reduced lung function at six years. In the subgroup analysis, the 52 children exposed to NO2 levels from the highest quartile during pregnancy, the first and second year of life and from birth until follow-up, had a significant decrease in FEV1. Per interquartile range increase of NO2, FEV1 decreased by [z-score change (95% confidence interval)] [-1.07 (-1.67 to -0.47)], [-1.02 (-1.66 to -0.39)], [-0.51 (-0.86 to -0.17)] and [-0.80 (-1.33 to -0.27)], respectively. Conclusion: Our results suggest that exposure to higher NO2 levels, which are still lower than WHO guideline limits, especially during the sensitive period of early lung development, may be associated with reduced lung function at school-age. This supports the concept of age and dose-dependent pollution effects and underline the importance of pollution reduction measures.
Images	
Caption Figure 1:	 Temporal development of mean NO2 (µg/m3) levels for each quartile.

Caption Figure 2:	 Effect of NO2 (µg/m3) levels on FEV1 (ml) at six years. The population was divided into quartiles by individual NO2 levels (per quartile n=52).

	Di Iorio Silvana
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Publication title	Understanding of Sub-23 nm Particle Emissions from PFI/DI SI Engines Fueled with Gasoline, Ethanol and Blend
Publication type	Poster
Introduction & Background	The internal combustion engines (ICEs) are still playing a dominant role in the powertrain vehicles although they are the main source of particle emissions in the urban area. Particle emissions are typically associated to Diesel engine, anyway direct injection spark ignition (DISI) engines play a relevant role in particle emissions because of the less time for fuel evaporation and mixing and because of the fuel impingement. The use of the oxygenated biofuels allows reducing the particle emissions. For the SI engines ethanol is the most used alternative fuel because of the higher octane number and the higher heat of vaporization compared to gasoline. Anyway, typically emit a larger number of particles smaller than 100 nm. Several studies have pointed out that health effect on human health is strongly related to particle number and size. For this reason, a particle number (PN) emission limit of 6 × 1011 #/km from Diesel and DISI engines was introduced. Anyway, only particles larger than 23 nm were taken in to account. Several researches evidenced a large presence of particles smaller than 23 nm from both Diesel and SI engines. The emissions of sub-23 nm particles can be more harmful to human health than bigger particles as they have higher deposition efficiency in the respiratory system and can translocate to other areas such as the brain. Their nature is not fully clear and their measure can be biased by the sampling conditions. The necessity to better understand the nature of sub-23 nm particles to define a proper procedure to measure them leads to the promotion of several European projects that aims to characterize particle nature as well as to develop instruments that can measure particle smaller than 23 nm.
Methodology	In order to properly define a measurement procedure for particle number emissions of the internal combustion engines it has to be better characterize the effect of the sampling parameters on the sub-23 nm particles. This paper aims to understand the sub-23 nm particle nature by means of the analysis of the effect of the temperature of sampling. The investigation was performed on small displacement SI DI/PFI engines fueled with gasoline, ethanol and a blend of 25%v/v of ethanol in gasoline. The tests were carried out at full load and 2000 and 4000 rpm representative of the European homologation urban driving cycle. Particle emissions were measured by means of a smokemeter, to measure the particle concentration at raw exhaust, and an Engine Exhaust Particle Sizer (EEPS), for the measurement of number and size in the range from 5.6 to 560 nm. The tests were carried out at two sampling conditions, Cold and Hot in order to estimate the presence of Volatile Organic Fraction (VOF).
Results & Conclusions	The results evidenced that the presence of sub-23 nm particle and of the VOF are strongly dependent on fuel and engine conditions. For each fuel, the sampling conditions play a governing role on the measurement of the sub-23nm particles highlighting the necessity to define a proper measurement protocol for their measure.

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Coauthors	Yvain Carpentier; Marin Vojkovic; Adam Boies; Mustafizur Rahman; Claire Pirim; Cristian Focsa
Publication title	Size-selective sampling and chemical characterization of ultra-fine particulate matter emitted by a direct injection single cylinder gasoline engine
Publication type	Poster
Introduction & Background	Particle emissions from on-road motor vehicles are fast becoming a big social concern due to their high toxicity and climate impact. Despite that, there is a critical lack of certification procedures under real driving conditions and for the smallest particles, down to 10 nm. The development of such measurement procedures would provide an important contribution towards both the future particle emission regulations and the development of new engine technologies. In the framework of the H2020 PEMs4Nano project (www.pems4nano.eu) a measurement procedure down to 10 nm will be developed/achieved, also providing a contribution to regulations on particle emissions for real driving conditions. The development of a measurement procedure that will be reliable and precise requires a deep understanding of the emitted particle characteristics (e.g. morphology, structure, chemical composition, volatility, reactivity), especially their variation with the size. This work presents a study on the influence of the catalytic stripper on size-selected particles emitted by a direct injection gasoline engine.
Methodology	Particulate matter investigated in this work was produced by a generic single-cylinder engine that could be operated in various working regimes. Particles were then sampled with and without a catalytic stripper using a cascade impactor (NanoMoudi-II, TSI) which allows size-separation of sampled particles into 13 different size bins. The main goal of the project is the study of small particles, down to 10 nm, therefore only particles from the lower size bins of the cascade impactor were analyzed. The chemical characterization of the collected particles is performed using a custom built Time-of- Flight Mass Spectrometer (ToF-MS) instrument coupled to a laser desorption/ionization technique (L2MS). Various ionization methods developed in our laboratory are used, including VUV sources, thus allowing a selective detection of aliphatic and aromatic species. Furthermore, additional information is obtained on such molecular classes as organosulfates, oxygenated hydrocarbons, nitrogenated hydrocarbons, heavy metals and polycyclic aromatic hydrocarbons (PAHs) – main precursors of soot particles. Additional high-resolution chemical characterization is performed with a Secondary Ion Mass Spectrometry (SIMS) instrument which provides a high sensitivity for both inorganic and organic species. Statistical procedures, such as principal component analysis (PCA) and hierarchical clustering analysis (HCA), were used to emphasize subtle differences and similarities in mass spectra of differently-sized soot particles sampled with and without a catalytic stripper, thus revealing a significant change of their chemical composition.
Results & Conclusions	It was shown that the smallest particles are the most affected by the catalytic stripper due to their higher surface organic fraction which was also confirmed by on-line aerodynamic-mass-mobility measurements. Mass spectroscopic studies of size-selected particulate matter sampled with and without a catalytic stripper in combination with advanced statistical procedures provide critical physico-chemical data necessary to develop measurement procedures down to 10 nm within the PEMs4Nano project.

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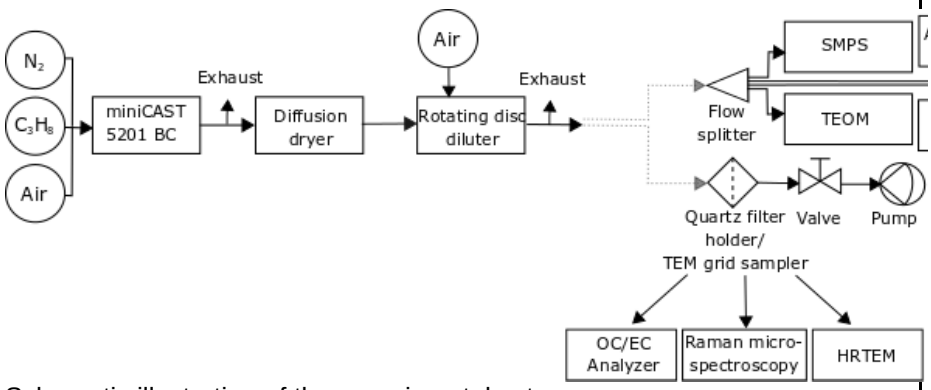
Publication title	Optical and morphological characterization of "miniCAST 5201 BC"-soot
Publication type	Poster
Introduction & Background	Carbonaceous particulate matter, such as Black Carbon BC or Brown Carbon BrC, are monitored in the atmosphere or directly measured at emission sources as they are known to have a large impact on climate and human health. For reliable and comparable results, BC measurement instruments should be calibrated with traceable and standardized calibration procedures. To this end, stable, reproducible and well-characterized soot aerosol generators are necessary, producing particles with well-defined physical characteristics. The new miniCAST 5201 BC generator (Ess & Vasilatou, 2019) is a promising candidate generator as it permits to a large extent the decoupling of particle size from composition. The physical and optical properties of the produced soot aerosols have been therefore further characterized by an array of experimental methods.
Methodology	The miniCAST Model 5201 BC (Jing Ltd.) was used, operated under various conditions (diffusion flame, partially premixed flame, fuel-lean and fuel-rich conditions). Seven set points generating particles of different size and composition have been selected to be comprehensively analysed by means of particle number size distribution (scanning mobility particle sizer SMPS), mass concentration (tapered element oscillating microbalance TEOM), nanostructure (Raman microspectroscopy, (high resolution) transmission electron microscopy TEM/HRTEM), composition (elemental and organic carbon EC/OC analysis) and their optical properties (aethalometer and photoacoustic extinctiometer PAX).
Results & Conclusions	Particles with geometric mean mobility diameters 50-160 nm and high EC/TC mass fraction (>85 %) generated at fuel-lean near-stoichiometric conditions of a diffusion flame (160 nm) or with partially premixed flames (50-100 nm) could be assigned a turbostratic, partially onion-like, structure of the primary particles. The optical properties indicated BC-like materials with low wavelength dependence of the absorption (Angstrom absorption exponent AAE < 1.2) and low single scattering albedo (SSA < 0.1 at 870 nm). The mass absorption coefficient MAC (from PAX-based absorption and TEOM mass) ranged from 4.3 to 3 m2/g at 870 nm, decreasing with decreasing particle size. The particles with geometric mean diameters 50-100 nm generated at fuel-rich conditions, instead, possess lower EC/TC mass fractions (6-50 %) and a turbostratic nanostructure with pronounced amorphous regions. Moreover, additional bands appear in the Raman spectra assigned to vibrations of organic compounds. In addition, the optical measurements revealed higher AAE (1.7-3.4) and higher SSA (~0.2 at 870 nm) indicating a much higher organic carbon content. Thus, with the miniCAST BC a variety of particle sizes with different properties can be generated in a stable and reproducible way (e.g. 50-160 nm BC-like particles), making this generator a promising calibration aerosol source. This work is part of the 16ENV02 Black Carbon project funded by the

	European Union through the European Metrology Programme for Innovation and Research (EMPIR). METAS was supported by the Swiss State Secretariat for Education, Research and Innovation (SERI) under contract number 17.00117. References: Ess, M.N., and K. Vasilatou (2019). Aerosol Sci. Technol. 53:1, 29-44.
Images	
Caption Figure 1:	 Schematic illustration of the experimental setup.

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Publication title	Ultrafine particle measurements at Zurich Airport
Publication type	Poster
Introduction & Background	Ultrafine particles are of growing interest in society and industry and Aviation is no exception. For many years, Airports have conducted studies and measurement campaigns to better understand emissions and resulting concentrations fom Aviation related particles. Zurich Airport has conducted a comprehensive measurement Campaign in 2016, following an early scoping study in 2012 to address to Topic and has continued measuring in 2018 und 2019.
Methodology	For the 2016 study, a total of 10 measurement devices, a miniDiSC have been used simultaneously at Zurich Airport (with one device placed distant to the Airport). They measured the total particle number, the average diameter and the LDSA. The Setup allowed to consider North-South and East-West transects as well as Apron and runway Differentiation. The Campaign ran over several weeks to be reflective of various weather situations.
Results & Conclusions	Results from the 2016 study showed a very high spatial and temporal Variation both for individual stations in themselves and between close by stations. Results showed a high wind dependency with a rapid concentration decrease within short distances.
Images	
Caption Figure 1:	 MiniDiSC

Caption Figure 2:	 Aircraft Take-Off

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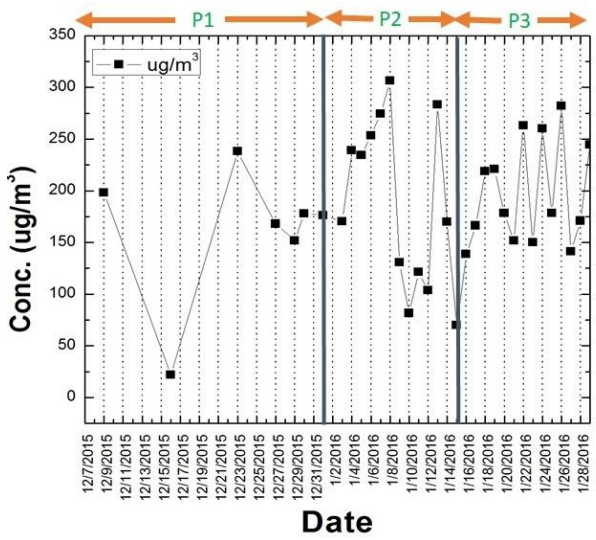
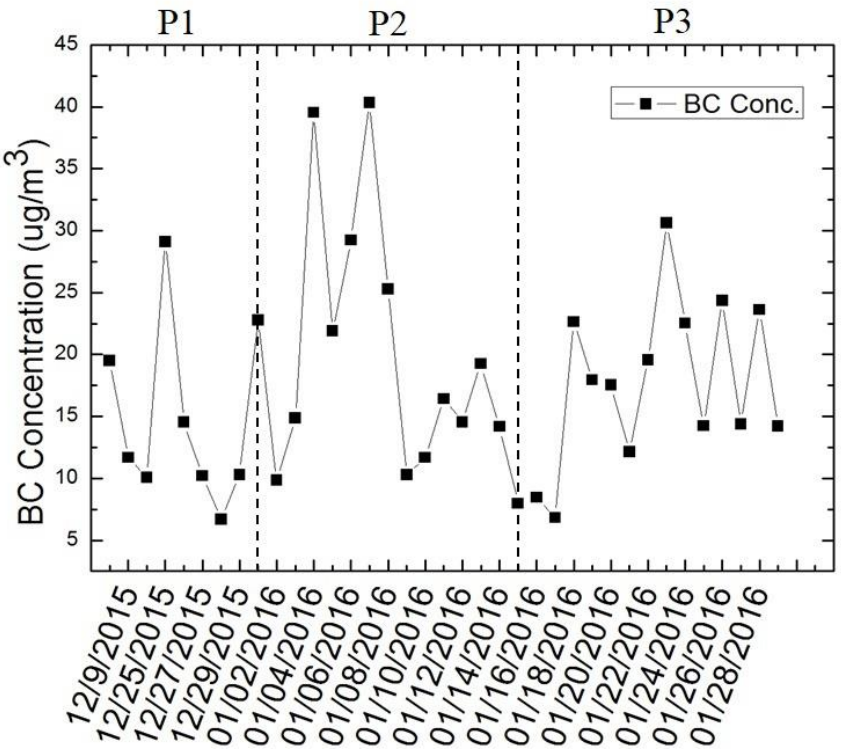
Publication title	Effect of Road Space Rationing Policy on PM Characteristics: A case study over Delhi
Publication type	Poster
Introduction & Background	Air pollution has become the fourth highest risk factor for premature death globally. In India itself, air pollution causes nearly 1.59 million deaths per year. Unfortunately, Delhi has been listed among the most polluted cities of the world where the living beings are suffering from several cardiovascular and respiratory diseases. In view of this, Delhi government has implemented vehicular emission control policy to ensure good air quality in the winter of 2016 by implementing the road rationing policy from 1-15 January, 2016. According to the scheme, the odd numbered private cars were allowed on the road on odd dates only and even numbered on even dates only.
Methodology	Measurements were carried out at CSIR-NPL using Envirotech® APM550 (for collecting PM2.5), AE51 aethalometer (for real time black carbon, BC measurement), temperature and humidity sensors. PM2.5 particles were analysed using wavelength dispersive X-ray fluorescence spectroscopy to investigate their elemental composition. The sampling period was divided into three categories; Phase 1 (P1, 1-31 Dec 2015), Phase 2 (P2, 1-15 Jan 2016) and phase 3 (P3, 16-31 Jan 2016) period.
Results & Conclusions	During the study period, the BC and PM2.5 mass concentration were observed to be ranging from 6.7 to 40.33µg/m3 and 21.94 to 283µg/m3, respectively. The average BC and PM2.5 mass concentration during P1, P2 and P3 were measured to be 14.01µg/m3, 19.87µg/m3, 17.79µg/m3 and 163.51µg/m3, 186.98µg/m3 197.45µg/m3, respectively. The lowest (6.7µg/m3) and highest (40.33µg/m3) BC concentration were observed on 28 December, 2015 (P1) and 7 January, 2016 (P2). Figure 1&2 shows the daily variation of BC and PM2.5. During the entire study period, the mean PM2.5 mass concentration was measured to be 186.98µg/m3 which was substantially higher than the standards set by Indian National Air Quality Standard [i.e. 60µg/m3 (www.cpcb.nic.in)] and the US National Ambient Air Quality Standards [i.e. 35µg/m3]. In the present study, the reduced traffic density was not found to be sufficient to make visible decrease in BC and PM2.5 mass concentration. The daily variation of meteorological parameters was found to superimpose the effect of reduced traffic density.
Images	

Caption Figure 1:	 Daily variation of BC mass concentration during phase 1 (P1, 1-31 Dec 2015), Phase 2 (P2, 1-15 Jan 2016) and phase 3 (P3, 16-31 Jan 2016).
Caption Figure 2:	 Daily variation of PM2.5 mass concentration during phase 1 (P1, 1-31 Dec 2015), Phase 2 (P2, 1-15 Jan 2016) and phase 3 (P3, 16-31 Jan 2016).

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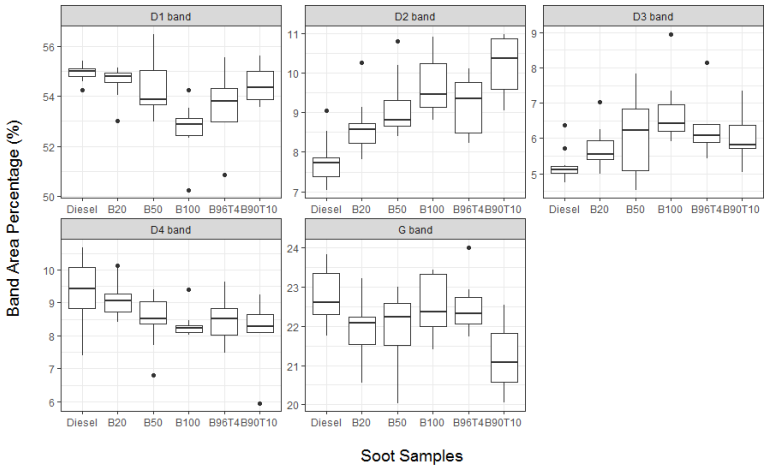
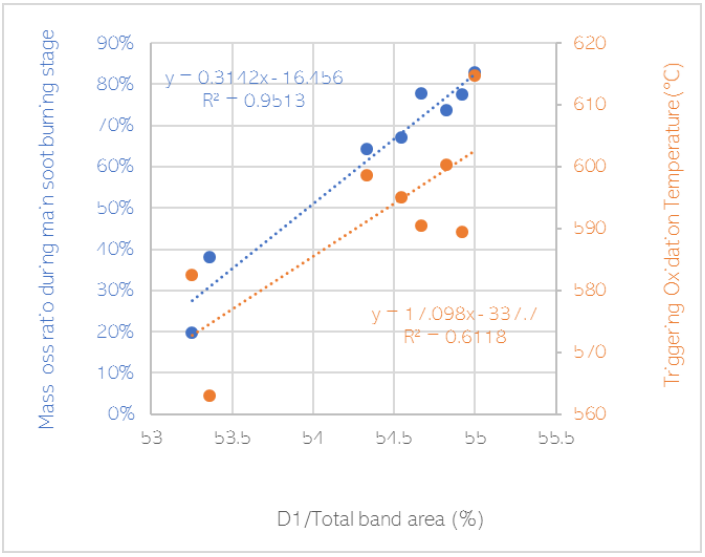
Publication title	Diesel soot thermal decomposition investigation based on chemical structure
Publication type	Poster
Introduction & Background	Diesel particle emission has been a major concern in the environment sector in recent decades. Since the application of the diesel particulate filter (DPF) the diesel particle emission has been significantly reduced. However, the large amount of soot trapped requires to be burnt off to regenerate the DPF. The Thermal decomposition of diesel soot is an oxidation process, which relates to the chemical structure of the diesel soot. Understanding the diesel soot decomposition process is of great significance for removing carbon efficiently and setting up DPF regeneration, as well as for controlling the emission produced in the regeneration stage potentially. The present study is to investigate the function groups of carbon in the diesel soot in order to explore how these function groups participate during soot thermal decomposition.
Methodology	The Differential Scanning Calorimetry and the Thermal Gravimetric Analyser were applied to investigate the characteristics of the thermal decomposition of diesel soot. These techniques enabled us to obtain the mass loss versus temperature, triggering oxidation temperature (TOT) and other thermal parameters. For the soot structure analysis, Raman Microscopy was employed to obtain the soot Raman spectra and the five bands model was applied to perform the peak fitting. The crystalline graphite (G band), aromatic sp2 carbon (D1 band), defects of edge carbon (D2 band) and amorphous carbon involving organic molecules (D3 band), as well as polyenic chains (D4 band) are characterised in the diesel soot. Regarding the soot sample generation, the convention diesel, coconut biodiesel and Triacetin were used and blended in different percentage with scaling of oxygen contained in the blends of fuel. The order of increasing oxygen content is: Diesel (convention diesel, with zero oxygen), B20 (20% biodiesel with 80% diesel, 2.2% oxygen content), B50 (50% biodiesel with 50% diesel, 5.5% oxygen content), B100 (pure coconut biodiesel, 11.0% oxygen content), B96 (96% biodiesel with 4% triacetin, 12.0% oxygen content) and B90(90% biodiesel with 10% triacetin, 14.0% oxygen content). The combustion was undertaken in the Cummins ISBe220 31 diesel engine with identical working condition for all the blends.
Results & Conclusions	Overall, with an increase in the biodiesel blend in the fuel, the more amorphous carbon and organics contained in the soot after combustion, while less graphite and aromatic sp2 as well as chain polyenic carbon, which are all tied to the double bonds in the carbon. Figure 1 is the percentage of each band in the varied soot samples. This means that with more oxygen contained in the fuel, the combustion process is more complete, then less double bonds in the diesel soot. The double carbon bonds, especially aromatic sp2 bonds (represented by D1 bands) are proportional to soot mass loss in the main soot decomposition stage, which indicates the double bonded carbon is predominantly consumed. Also, the aromatic sp2 correlates with the TOT, which is an important parameter for DPF regeneration. This implies that temperature for DPF regeneration can be related to the double carbon bonds in the retained soot as shown in Figure 2.

Images	
Caption Figure 1:	 The five Raman bands area percentage in varied diesel soots
Caption Figure 2:	 Figure 2. The correlation between soot thermal decomposition characteristics and D1 Raman band area

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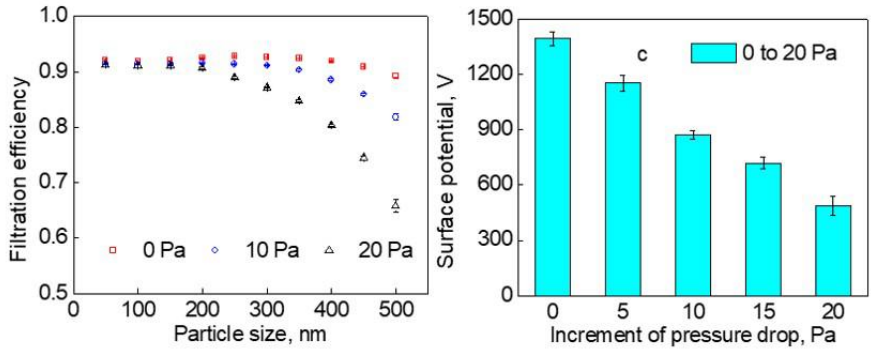
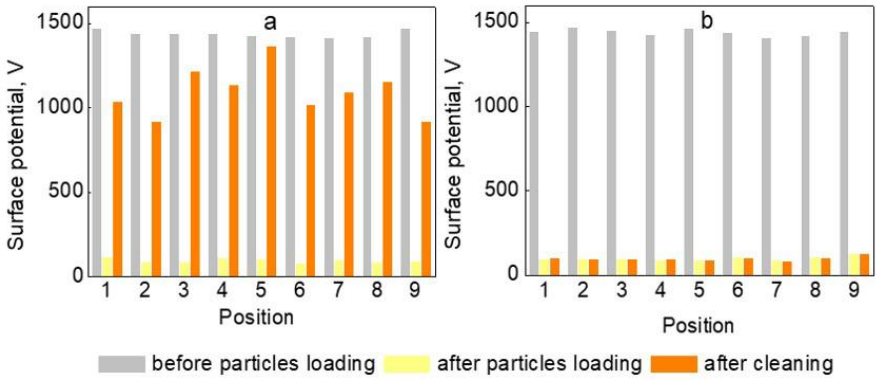
Coauthors	Fuze Jiang; Yinghe Guo; Jingxian Liu; Jing Wang
Publication title	The Filtration Performance of Electret PTFE Filter during Soot Particles Loading and Reusability
Publication type	Poster
Introduction & Background	More and more attention has been paid to the effect of particles deposition on electret filter in long-term performance (Shi and Ekberg 2015; Tang et al. 2018). Soot particles produced by combustion can cause the loss of efficiency of electret filters (Brown 1988), which should be specially considered. In this study, the filtration performance of charged PTFE needle felt filters (PNFF) during the loading process were investigated using soot particles. Additional experiments were carried out to investigate the reusability of the electret filter.
Methodology	The PNFF were charged via positive corona discharge, and filter surface potential was monitored with an electrostatic voltmeter (Monroe 244 A). The detailed set up as well as filtration performance tests were presented in previous publications extensively (Wang 2014, Sachinidou 2018). The filtration efficiency of the charged PNFF during the particles loading process was measured at the filtration velocity of 5 m min-1. A soot generator (Series 6200 Low-Mass miniCAST, Jing Aerosol) was used to produce particles for the loading test. To evaluate the reusability of the electret filters, charged PNFF were challenged by both soot particles and mixed dust which consisted of the soot particles and ISO 12103-1, A2 fine test dust. The surface potential was measured after cleaning up.
Results & Conclusions	Corresponding to the attenuation of the surface potential when particles began to deposit on the fibres, the filtration efficiency of charged PNFF decreased (Fig 1). The surface potential of the charged PNFF loaded by soot particles did not change after cleaning up, whereas the charged PNFF loaded by mixed dust (soot particles and A2 dust) could recover more than 67% of the initial surface potential after cleaning up (Fig 2a). By controlling the characteristics of dust cake, the reusability of electret filters after cleaning up can be improved.
Images	
Caption Figure 1:	 Filtration efficiency and surface potential of the charged PNFF during particles loading process

Caption Figure 2:	 Surface potential of charged PTFE needle felt filter in a) loaded by mixed dust b) loaded by soot particles

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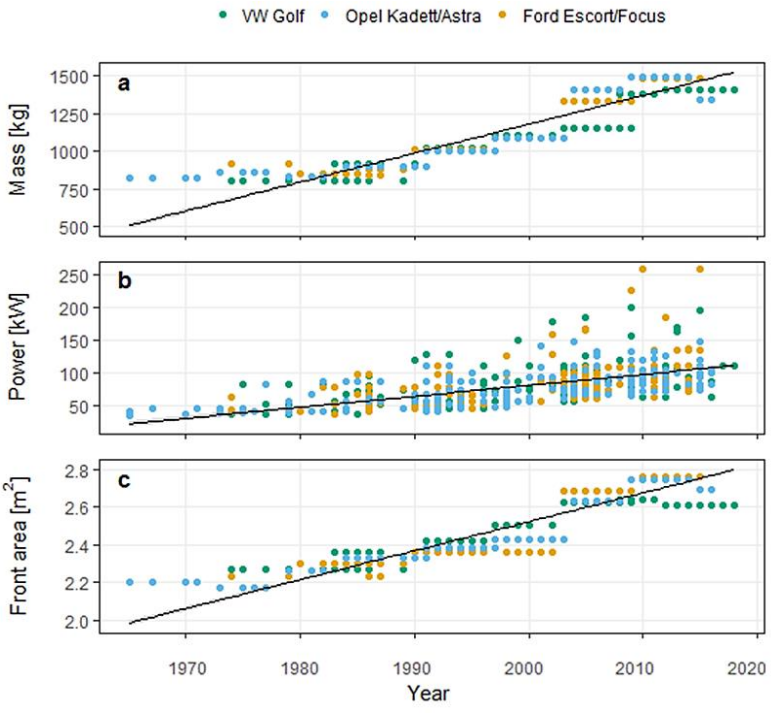
Publication title	Power and mass growth of popular cars since 1980 and resulting efficiency losses
Publication type	Poster
Introduction & Background	The continuous growth in the mass and power of new passenger cars in Europe absorbs a considerable part of improvements in powertrain efficiency. The related efficiency trade-offs and excess CO2 emissions for three most popular compact cars sold in Germany have been investigated for the first time.
Methodology	The investigation is based on a regression analysis of 1,645 individual model variants. The findings were verified in a sensitivity analysis for 700 model variants comprising small, compact and mid-size cars.
Results & Conclusions	While mass and power of model variants increased by 66% and 150% between 1980 and 2018, fuel consumption decreased 11% for gasoline models but it increased 0.4% for diesel models in the same period. However, fuel consumption could have decreased by 23% and 24%, respectively if mass and power of models had remained at 1980 levels. The resulting trade-offs amount to 51% and 102% of the efficiency improvements, or 24 g CO2/km for gasoline cars and 40 g CO2/km for diesel cars, respectively. For the sensitivity analysis covering 700 model variants, the resulting efficiency trade-offs are even larger. Concluding, a substantial share of CO2 savings due to engineering progress was not arriving at the streets in the last decades, which probably goes back to a legislation that grants carmakers higher CO2 emissions for heavier vehicles.
Images	
Caption Figure 1:	

	Time series of mass (a), power (b), front area (c) of model variants of the three compact cars. Data sources: Spritmonitor (2018a), Kittler (2001a,b), Oswald (2001), Wikipedia (2018)

	Hu Zhiyuan
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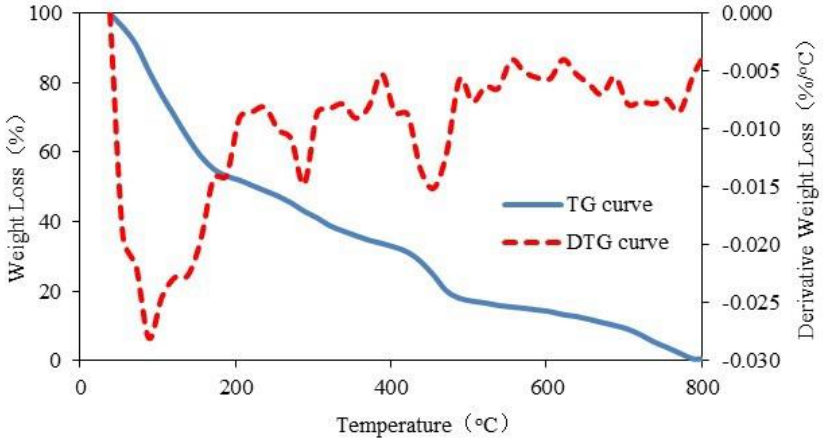
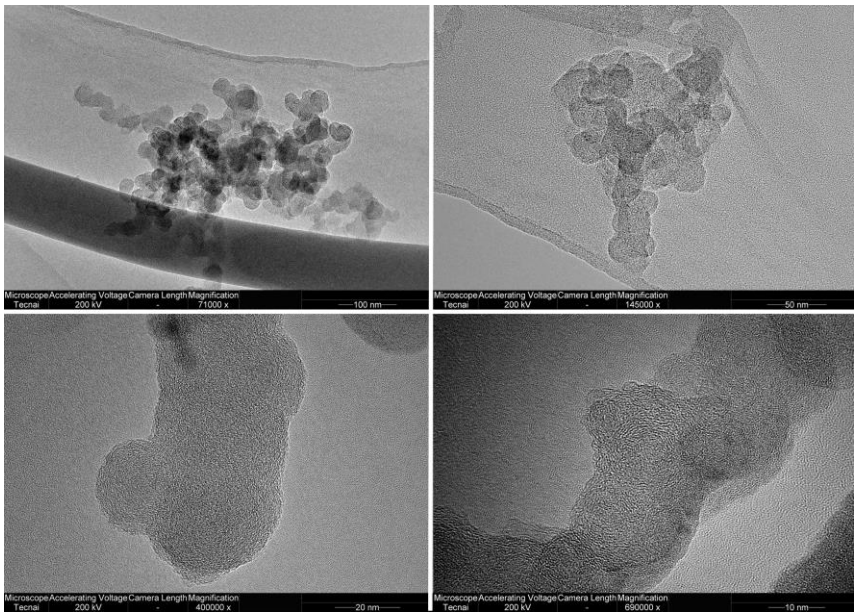
Publication title	Effect of Temperature on Oxidation Reactivity and Nanostructure of Particulate Matter from a China Ⅵ GDI Vehicle
Publication type	Poster
Introduction & Background	Particulate matter (PM) emissions have become one of the serious environmental pollution problems, and it's the main resource of aerosol haze. As known, PM is composed of soluble organic fraction (SOF), dry soot and ash. Polycyclic aromatic hydrocarbons (PAHs) in the SOF have been manifested to induce human cancer. Moreover, PM can be absorbed by human lungs and spread to other organs, then it leads to some sickness such as asthma, bronchitis or exacerbating allergies. Gasoline Direct Injection (GDI) engines become the current trend for gasoline powertrains because of a multitude of advantages. As an example, GDI shows the increased power output, higher engine efficiency. Consequently, the number of GDI vehicles was increasing in past a few years. GDI engines have been demonstrated to produce more PM than conventional port fuel injection gasoline engines. Besides, taking the vehicle as the research object rather than an engine could better reflect the results of particulate matter formation in the actual operation process. During real road drive emission process, secondary particles from vehicles could be more than engines. This would increase the difficulty of exhaust aftertreatment. Therefore, the physical and oxidation characteristics of GDI vehicles' PM need further research. The oxidation characteristics and nanostructure of flame soot and the diesel PM have been studied by many researchers before. However, GDI engine-generated PM shows some different characteristics. Oxidation reactivity and nanostructure are closed to the control strategies of GDI vehicles and the collection efficiency. A GDI vehicle certified to meet China Ⅵ emission standard was tested on a chassis dynamometer, the PM was collected by sampling system. By use of a thermogravimetric analyzer (TGA) and transmission electron microscope (TEM), the results were analyzed to the oxidation reactivity and the nanostructure of PM. This research revealed the relation between the oxidation reactivity and nanostructure of GDI PM, it could provide a theoretical basis for gasoline particulate filter regeneration further, and would lead in solving the problem of particulate matter pollution.
Methodology	In this study, a GDI Vehicle met China Ⅵ emissions standards was tested Worldwide-harmonized Light vehicles Test Cycle (WLTC) on a chassis dynamometer. The vehicle was driven following the WLTC under hot and cold start conditions. Diluted exhausts samples were collected with single channel sampling device. The samples were adsorbed on the quartz membrane that was a 47mm quartz filter membrane produced by Whatman. After processed following several cleanup procedures, final extracts were analyzed by post-offline device analysis. Measured the oxidation rate and observed the morphology of PM after heated in different temperatures. The thermogravimetric analyzer (TGA) was used to obtain oxidation rate parameters, and determine PM composition by proximate analysis. Transmission electron microscope (TEM) was used to determine the nanostructure with the average size of primary particles and the morphology of the agglomerates. The oxidation parameters of PM were calculated and fitted with the use of MTLAB. Special image processing program measured the characteristic parameters of primary particles, such as average primary particle size, fringe length and tortuosity. Compared the different oxidation reactivity and nanostructure parameters, obtained the effect of temperature on oxidation reactivity and nanostructure of PM.

Results & Conclusions	Major oxidation and nanostructure parameters of particle matter from GDI vehicle were investigated. During the oxidation process, the temperature of maximum mass loss rate is 455℃, which is lower than the current study results of GDI engine particle matter. When the particle matter are oxidized in the air, primary particles with fringe accumulated loosely are oxidized first, for the primary particles with onino-shell crystallitic, the core is oxidized first, and the hollow structure is formed at 600℃.In the oxidation process, the average value of primary particle diameter first decreased and then increased, the average value of fringe length and fringe separation first increased then decreased then increased, and the average value of fringe tortuosity increased. The distribution of diameter of primary particles, fringe length, fringe tortuosity and fringe separation are unimodal distribution with the peak value at 20~22nm, 0.2~0.4nm, 1.2~1.3 and 0.38~0.40nm respectively, the average values of them are 23.2 nm, 0.53nm, 1.36 and 0.40nm respectively. The results demonstrated the relation between oxidation reactivity and nanostructure, thus it could give future directions of research.
Images	
Caption Figure 1:	 Fig.1. TG curve and DTG curve of particle matters oxidized in air atmosphere
Caption Figure 2:	 Fig.2. TEM microphotographs of oxidized particles in different resolution ratio

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Publication title	Seasonal variability of PM2.5 composition and its sources over Delhi, India
Publication type	Poster
Introduction & Background	Worsening air quality has become the foremost perturb in the world, causing about 7 million global deaths as recently revealed by WHO, 2017 while 3.2 million annual deaths solely due to airborne fine particulates. To assess aerosol effects on air quality and climate, it is important to understand their primary and secondary sources and characteristics in time and space. The exigency to comprehend the potential source categories and their contributions (source apportionment) has become imperative to reduce the PM pollution.
Methodology	The seasonal variability of PM2.5 concentrations and composition were carried out over Delhi, India during January 2013 to December 2016. PM2.5 was analyzed for its chemical components. Trace metals (Al, Mg, S, Cl, K, Ca, Ti, Cu, Mn, Fe, Zn, Br, Cr, As, and Pb) were analyzed using Wavelength Dispersive X-Ray Fluorescence Spectrometer, water-soluble inorganic ionic component (Na+, NH4+, K+, Ca2+, Mg2+, F-, Cl-, NO3−, and SO42-) were analyzed using Ion-Chromatograph, organic carbon (OC) and elemental carbon (EC) were analyzed using OC/EC analyzer.
Results & Conclusions	The average concentration of PM2.5 was observed to be 131 ± 79 μg m−3 with maximum concentration during winters (183 ± 73 μg m−3) and minimum during monsoon season (69 ± 28 μg m−3). Source apportionment of PM2.5 has been carried out using Positive Matrix Factorization (PMF5) receptor model, characterizing the seasonal variabilities and resolved eight sources of PM2.5 (secondary sulphate, secondary nitrate, biomass burning, coal combustion, vehicular emissions, industrial emissions, crustal/soil dust and marine/sea salt) in urban area of Delhi. The results show that secondary sulphate is higher during summer (18% of PM2.5) while secondary nitrate is higher during winters (15% of PM2.5). The secondary nitrate is favored by low temperature while high temperature favors the formation of secondary sulfates. Biomass burning shows larger contribution during winter (14%) because of the influence of domestic heating, wood burning, however, this source is not negligible in summer (12%), likely because of the contributions of fires and agricultural practices. Contributions from vehicular emissions (23%) are higher during winters attributed to stable atmosphere and lower boundary layer height. Crustal/soil dust contribution (15%) is observed to be higher during summers attributed to strong winds and dust storms that prevail during the season.

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Publication title	A correlation analysis of between PEMS and SEMS according to develop SEMS device
Publication type	Poster
Introduction & Background	A study of RDE-LDV(Real Driving Emissions-Light Duty Vehicles) has been reported constantly since 2011. However, PEMS(Portable Emission Measurement System) is expensive and has complicated test procedure. Also, It has occurred frequent breakdown. In order to solve these problems, development of SEMS(Sensor Based Emission Measurement System) as been continuously carried out. SEMS is easy to operate and can be used for a long time.
Methodology	In this study, both PEMS and SEMS were installed in vehicles. SEMS used two devices. One can measure NOx emissions in 1Hz unit and the other can acquire NOx emissions in 10Hz unit. The tests obtained NOx Emissions of PEMS and data of NOx sensor of SEMS and OBD of vehicles to confirm correlation verification of between PEMS and SEMS. In case of RDE-LDV, a route satisfying regulation was developed to analyze NOx emissions from vehicles.
Results & Conclusions	As a result, the correlation of NOx emissions in WLTC test showed an average of 90% and the error rate was 10.3%. Compared with PEMS in RDE-LDV, the correlation of NOx emissions was 81.8% in the case of SEMS obtained in 1Hz unit, and showed an error rate of 7.58%. In the case of SEMS that acquires data in 10Hz unit, the average correlation is 90.5%, and the error rate is 7.8%. It was confirmed that it developed more than the previous 1Hz SEMS.

	Kammerer Matteo
Affiliation	Robert Bosch
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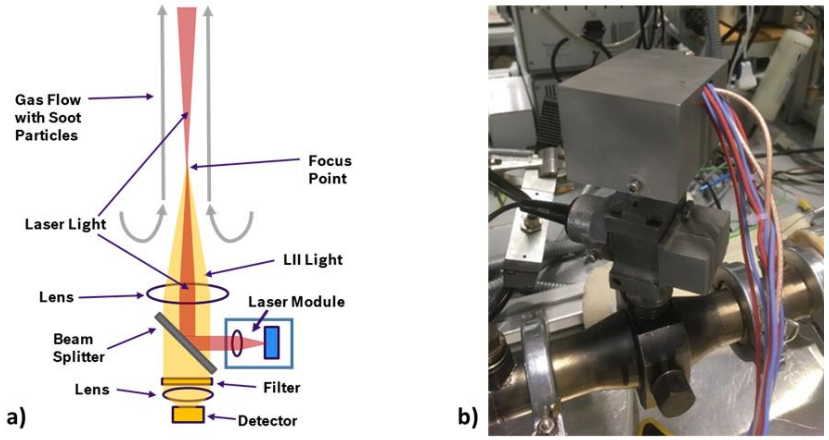
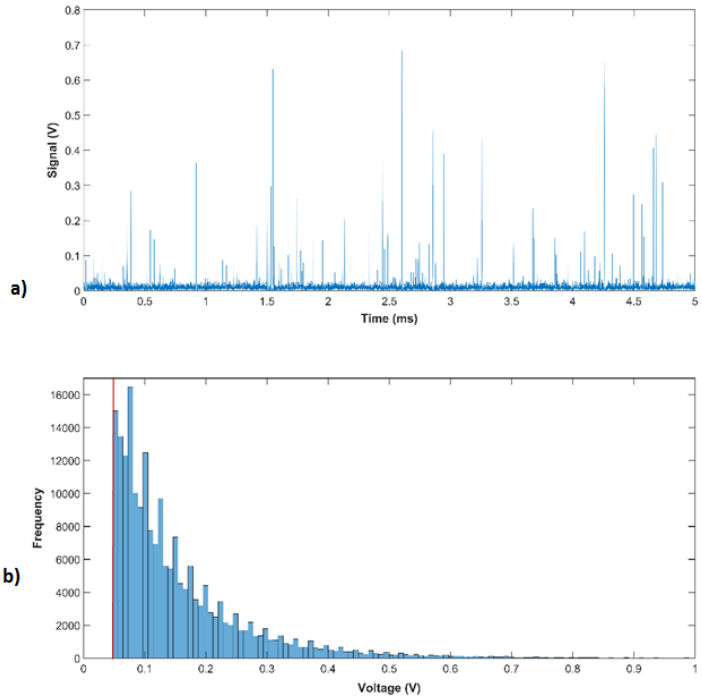
Publication title	A compact and mobile optical particle counting sensor based on continuous wave laser-induced incandescence
Publication type	Poster
Introduction & Background	Due to environmental concerns, there is a growing demand for the development of improved measurement techniques that are suitable for a precise determination of soot particle properties. Therefore, we present a novel sensor concept based on the principle of laser-induced incandescence (LII), which allows the investigation of nanoparticle properties such as number concentration and size. Whereas typical LII setups are designed for a laboratory setting, our approach enables a sensor with a more compact design to be used in varying measurement environments.
Methodology	Today, most LII systems rely on (nanosecond-) pulsed, high-powered Nd:YAG lasers to heat soot particles. A typical continuous wave equivalent optical output power value for the laser is 100 W. In contrast, our approach is based on focused light from a continuous wave laser diode in the visible or near-infrared spectral region with an optical output power of 100-300 mW. This enables a compact design suitable for mobile applications. In order to achieve a sufficiently high power density to heat particles close to their sublimation temperature, the focusing capability of the laser light is of great importance. With careful optical alignment, a focal spot with a spot diameter below 10 µm can be achieved, which leads to a power density in the focal spot of ~300 kW/cm². Particles travelling through the laser beam's focal spot are heated to temperatures above 3000 K due to absorption of the optical energy. The incandescent light emitted by the heated particles is captured using a confocal optical setup, as shown in Figure 1. The particle number concentration can be extracted from the amount of detected signal peaks and the known size of the focal spot. Since the intensity of the LII signal scales with the third power of the particle diameter, the magnitude of each individual output signal peak contains information about the particle size. The performance of the sensor demonstrator was investigated using soot particles generated with the propane flame of a miniCAST soot generator and transported to the demonstrator through a pipe. By comparing the output data with reference measurement devices, an analysis of the sensor's functionality and detection limits is performed.
Results & Conclusions	The measurement data shown in Figure 2 is generated with a sensor setup using a NIR laser diode (λ=830 nm, P=250 mW), as shown in Figure 1b). The functionality of this LII sensor concept based on focused light from a laser was successfully proven. Figure 2 shows exemplary measurement data, where peaks in the signal with varying magnitude caused by LII light from heated particles are clearly visible. With knowledge of the fluidic behaviour inside the sensor, the total particle number concentration can be calculated. A histogram of the peak voltages shows a clear correlation to the size distribution of the particles. Through a comparison with expected signals based on data from reference measurements, the sensor's current detection capabilities were examined. This initial analysis suggests that a particle diameter of 110 nm currently defines the lower detection limit. The incandescent light from smaller particles is below the threshold set by background radiation. Future work will include a reduction of the background radiation and an improved analysis of the output data.

Images	
Caption Figure 1:	 (a) Schematic representation of the LII sensor setup. Particles traveling through the laser beam's focal spot are heated and emit incandescent light. (b) Sensor demonstrator mounted in test bench.
Caption Figure 2:	 (a) Exemplary sensor output signal for a particle distribution with a mean particle diameter of 80 nm. Each peak in the signal represents the detected LII light from one heated particle. (b) Histogram of the peak voltage values for a measurement with a duration of 10 seconds. The vertical red line marks the current detection limit set by background radiation.

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Publication title	Effects of ethanol and aromatic levels on primary emissions and secondary organic aerosol (SOA) formation from GDI vehicles
Publication type	Poster
Introduction & Background	Aerosol particles from vehicle emissions are one the main contributors to impaired air quality and visibility in urban areas. It has been shown that, in many cases, the mass of secondary organic aerosol (SOA) formed as a result of photochemical oxidation of exhaust vapors in the atmosphere exceeds the emitted primary particulate matter. There are several factors affecting the formation of primary emissions and SOA, including engine technology and design, driving conditions, and fuel composition. Vehicles equipped with gasoline direct injection (GDI) engines have increased their market share in both the US and Europe, since this technology is considered one of the pathways to reduce greenhouse gas emissions and fuel consumption. However, GDI engines are known to produce more soot and ultrafine particle emissions than the traditional port fuel injection (PFI) engines or even diesel engines equipped with DPFs. Gasoline composition is also known to affect primary emissions and SOA formation potential. This is particularly true with aromatics, which are more prone to PM emissions than paraffins, isoparaffins, olefins, and oxygenates.
Methodology	This study included testing on three GDI vehicles with 2016 and 2017 model years operated on a range of different fuels over the LA92 test cycle. Two vehicles were flex fuel capable and were tested on two E10 fuels (one with low and one with high aromatic levels), an E30, and an E78 over cold-start and hot-start LA92 cycles. One conventional GDI vehicle was tested on eight fuels with nominal total aromatics targets of 20% and 30% (v/v) and ethanol levels ranging from 0% to 20% (v/v) over the cold-start LA92 cycle. Testing was conducted on a Burke E. Porter 48-inch single-roll electric dynamometer. A Pierburg Positive Displacement Pump-Constant Volume Sampling (PDP-CVS) system was used to obtain standard bag measurements for primary emissions. Diluted exhaust from the CVS was introduced to UCR's 30 m3 Mobile Atmospheric Chamber (MACh) over the duration of the driving cycles (excluding the hot soak).
Results & Conclusions	Results showed less straightforward effects on the primary emissions and SOA formation for the conventional GDI vehicle when operated on fuels with low ethanol concentrations (between 0 to 20% by volume) and varying aromatics. The ethanol's higher enthalpy of vaporization affected the formation of primary PM emissions and SOA production. The higher PM Index (PMI) fuels showed an upward trend for PM emissions and SOA formation with increasing ethanol content likely due to ethanol's evaporative charge cooling effect. For the flex fuel GDI vehicles, primary emissions and SOA formation reduced with higher ethanol fueling as a result of the chemically bonded oxygen and the OH bond, which promote the oxidation of soot precursors such as PAHs, as well as other VOCs that will likely act as SOA precursors. Our results revealed that an increase in aromatics in gasoline fuel will result in SOA increases and the potential degradation of urban air quality, while ethanol blends above 30% v/v will result in less SOA formation potential.

	Karg Erwin W.
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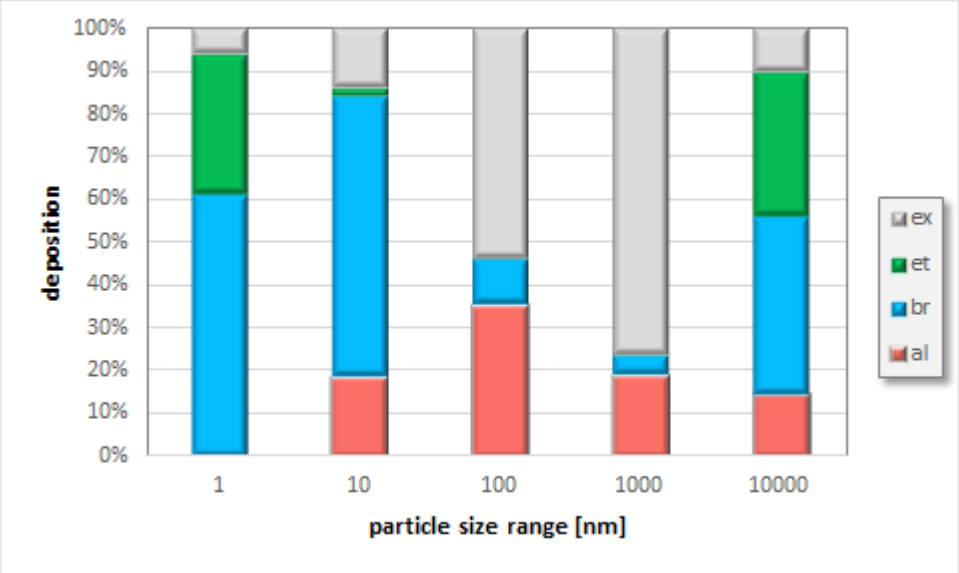
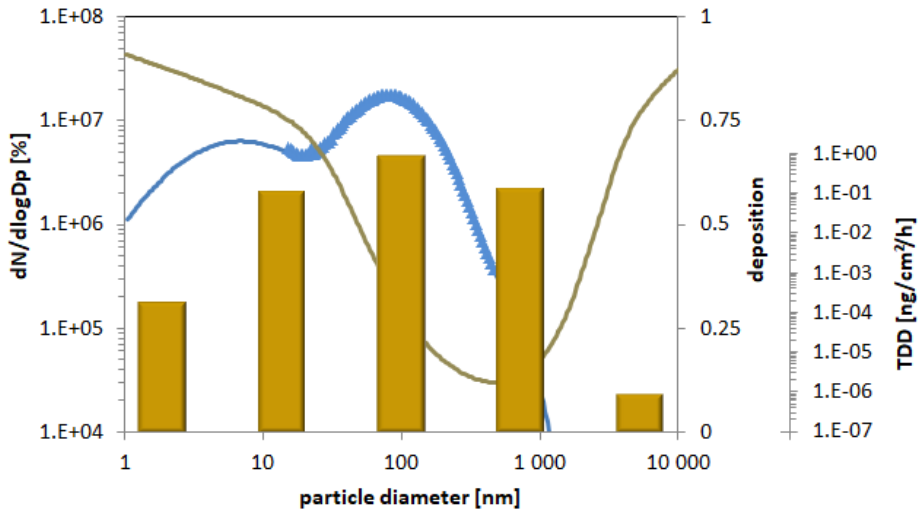
Email	karg@helmholtz-muenchen.de
Coauthors	George A. Ferron; Stefanie Bauer; Sebastiano Di Bucchianico; Ralf Zimmermann
Publication title	Why Detoxing All Combustion Engines? A Computer Model Approach to Regional Lung Deposition
Publication type	Poster
Introduction & Background	The regional lung deposition of inhaled substances can be determined by elaborative effort only. Computer software is available to reproduce the existing measured deposition data [1] on the one hand and to model lung deposition customized to a variety of parameters [2,3] on the other hand. Based on the HPLDB (hygroscopic particle lung deposition) model, deposition scenarios are adapted to both the characteristics of an emission aerosol and the properties of the respiratory tract (RT).
Methodology	From both, the emission size distribution and the lung deposition probability, the particle mass and number delivered to a certain surface area at the inner lung surface area is estimated (“tissue delivered dose” TDD). This allows also modeling particle mass and number deposited onto the surface area of a single cell in the RT.
Results & Conclusions	Deposition model output suggests four main size ranges: gas molecules, nanoparticles, ultrafine particles and micron sized particles. They are subjected to typical deposition regimes and can reach different lung regions. The deposition of gas molecules mainly depends on hygroscopicity and properties of the underlying tissue. Molecules and nanoparticles mainly deposit in nose and extrathoracic region, ultrafine particles in the alveolar and micron sized particles in the bronchial region (Fig 1). Selected monodisperse size distributions emblaze the deposition characteristics in the RT and emphasize the importance of nano sized and ultrafine particles for the burden of the deep lung and the alveolar tract. Measured size distributions from Diesel emission (Fig 2), wood smoke, aged particles and re-suspended dust serve as examples for the variability of regional deposition depending on particle characteristics. Depending on the emission characteristics of a combustion process, molecules and particles yield a regional lung burden depending on their size and structure. Modifying these characteristics results in modified regional lung burden and as a consequence in modified health effects. Therefore, we should aim for a full detoxication of emissions. For the correlation with health effects, modeling the TDD from gaseous and particulate exposure may be the better metric than using data from ambient sampling alone.
Images	

Caption Figure 1:	 Lung deposition model for non-hygroscopic particles (σg = 1.6): deposition in the extrathoracic (et), bronchial (br) and alveolar (al) lung region and particle fraction exhaled from the lungs (ex)
Caption Figure 2:	 Diesel size distribution (blue; dots: measured; line: fitted), deposition (gold) and tissue delivered mass (columns) for five size ranges

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Affiliation	ETH Zurich
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Coauthors	Alexander Bruun; Sotiris E. Pratsinis
Publication title	Impact of organic carbon on soot light absorption
Publication type	Poster
Introduction & Background	During incomplete combustion of hydrocarbons, soot agglomerates of chemically-bonded and polydisperse primary particles are formed (Kelesidis et al., 2017). Soot has a major contribution to global warming (25% of the total anthropogenic contribution) that is currently estimated with the highest uncertainty (90 %) among all contributors (Bond et al., 2013). This uncertainty can be attributed to the soot light scattering and absorption that depend on soot morphology and composition (Kelesidis & Pratsinis, 2019). The optical properties of soot are estimated by global climate models using the Mie theory for spheres, neglecting the soot morphology and composition that varies between different combustion sources and residence times (Bond et al., 2006). Thus, more detailed models are needed to quantify reliably the soot contribution to global warming. Soot produced from diffusion flames consists of refractory organic carbon (OC) in addition to elementary carbon, due to the rather low flame temperatures (Malmborg et al., 2019). The average soot OC content increases with increasing dilution or decreasing oxidant rates (ibid). Volatile and semi-volatile OC absorbs mostly UV light (Adler et al., 2010). The impact of OC on soot light absorption has not been quantified yet, impeding the accurate estimation of soot climate impact.
Methodology	Here, the impact of OC composition on soot optical properties is quantified by DEM-DDA for surface growth and agglomeration. The refractive index of the DEM-derived soot agglomerates is varied based on their OC composition using the Bruggeman theory.
Results & Conclusions	Neglecting the fractal-like structure of soot agglomerates containing OC results in mass absorption cross-section, MAC, that is more than 2 times larger than the measured one. The soot MAC derived by DEM-DDA accounting for the detailed soot morphology and composition is in agreement with measurements of soot agglomerates containing OC between 8 - 50 % and sampled from diffusion flames. Simple relations between soot MAC and its OC composition are derived to facilitate the accurate estimation of soot contribution to global warming.

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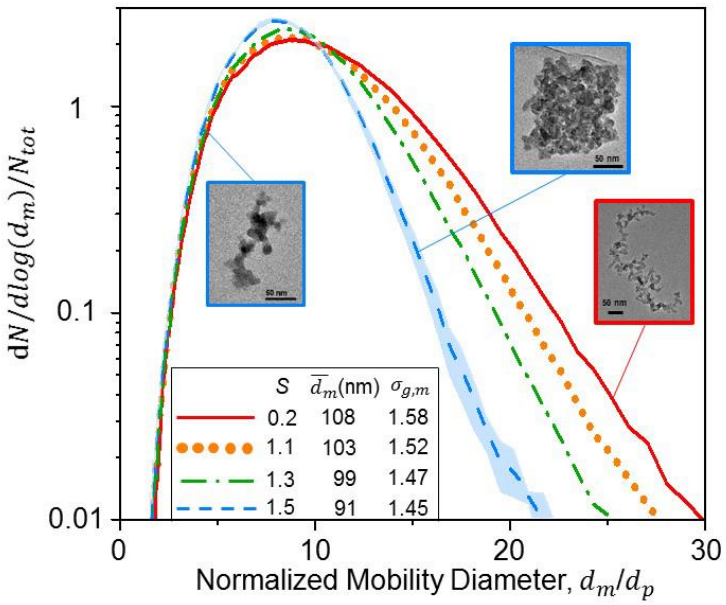
Publication title	Impact of humidity on silica nanoparticle agglomerate structure and size distribution
Publication type	Poster
Introduction & Background	Fractal-like agglomerates of physically-bonded single primary particles and/or chemically bonded ones (aggregates) are typically formed by coagulation during combustion. Furthermore, such agglomerates emitted by combustion engines (e.g. soot) or found in volcanic ash (e.g. silica) are of concern to human health and environment (e.g. climate forcing). This ramified agglomerate morphology changes drastically during atmospheric aging in the presence of vapors, such as humidity (Ma et al., 2013). Soot agglomerates restructure by water condensation and evaporation into smaller, more compact entities (ibid). The impact of humidity on metal oxide nanoparticle agglomerates, such as silica, has not been quantified yet. More compact silica agglomerate structures could exhibit increased light scattering (Radney et al., 2014) and lung deposition (Rissler et al., 2012), affecting silica nanoparticle impact on health and environment.
Methodology	Here, the restructuring dynamics of flame-made silica agglomerates during water condensation and evaporation are investigated. Therefore, an aerosol of silica agglomerates is mixed with humidified air at various temperatures resulting in saturation ratio, S, ranging from 0.2 to 1.5. Subsequently, these aerosols are dried through a diffusion dryer and their effective density, ρeff, primary particle, dp, and mobility diameters, dm, are measured by a scanning mobility particle sizer coupled with an aerosol particle mass analyzer, as well as by microscopy.
Results & Conclusions	The effect of water condensation-evaporation on flame-made silica agglomerate morphology and size distribution is quantified for the first time. Humidified-dried silica agglomerates restructure in response to attractive capillary forces induced for S > 1. As a result, these agglomerates are compacted into smaller structures. Larger agglomerates restructure more than smaller ones, decreasing the average mobility diameter dm by 15 % and geometric standard deviation, σg,m, by 20 % (Fig. 1). After humidification at critical S = 1.5 and subsequent drying, these agglomerates collapse into even more compact structures with a relative effective density ρeff/ρ = 0.28 ± 0.02, where ρ is the silica bulk density. This average silica agglomerate ρeff/ρ is smaller than the 0.36 ± 0.04 measured for soot (Ma et al., 2013) due to the hydrophilic surface and larger silica aggregate sizes (Kelesidis et al., 2018). Most importantly, this ρeff/ρ of 0.28 ± 0.02 is invariant with agglomerate dm, revealing a drastic difference between collapsed and as-prepared or untreated agglomerates.
Images	

Caption Figure 1:



Mobility size distributions of silica agglomerates humidified at S = 0.2 (solid line), 1.1 (dotted line), 1.3 (dot-broken line) and 1.5 (broken line) followed by drying. The mobility diameter, dm, is normalized by the average primary particle diameter, dp = 11.9 nm, obtained by microscopy [adapted from Kelesidis et al., 2018].

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Coauthors	P. Specht; P. Steigmeier; M. N. Ess; K. Vasilatou
Publication title	The Synthetic Carbonaceous Atmospheric Aerosol (SCAA) generator: towards the creation of an atmospheric aerosol standard
Publication type	Poster
Introduction & Background	Atmospheric particulate pollution has been linked to a broad spectrum of adverse health effects including respiratory problems, cardiovascular diseases and cancer. These effects depend not only on physical, but also on chemical properties of airborne particulate matter (PM) though to date it has proven difficult to disentangle the relative contribution of PM constituents to the reported population-level health effects. Particles in ambient air usually consist of a solid fraction, such as elemental carbon or minerals, and a more or less volatile fraction. Depending on temperature and volatility, this fraction may condense on the surface of preexisting particles, remain in the gas phase or nucleate and form new particles. This is strongly influenced by chemical reactions occurring in the atmosphere (mainly atmospheric oxidation known as aging) that lead to the formation of secondary organic matter (SOM). Comparison of results between different research groups is difficult, on the one hand, due to the diversity of experimental procedures, especially for health effect studies, but also due to the complex and non-constant nature of atmospheric samples. A stand-alone stable aerosol generator mimicking atmospheric carbonaceous aerosols with tunable characteristics, e.g., coating size and composition or “atmospheric age” would help our understanding of the properties of the ambient aerosol mixture.
Methodology	Within the framework of the EMPIR-AeroTox project (starting June, 2019), the University of Applied Sciences Northwestern Switzerland will develop a portable device consisting of a “tailored” reference aerosol source mimicking real life atmospheric aerosols. The device will integrate in its design a mini oxidation flow reactor (also known as micro smog chamber [1-3]) in order to coat primary particles with SOM. This will enable, for the first time, to generate combustion particles simulating a large range of atmospherically relevant situations with the use of a single, portable device. We have performed an initial pilot study, using a manually controlled laboratory setup in order to demonstrate the feasibility of our approach. Elemental carbon cores, generated by means of a miniCAST 5201 BC (Jing AG) [4], were coated with SOM from 1,3,5-trimethylbenzene, achieving a stable and reproducible aged aerosol with an elemental-carbon-to-total-carbon ratio between 0.80 (uncoated soot with number based geometrical mean diameter, GMD=90nm) and 0.12 (coated particles of GMD=160nm with GMD=90nm soot core) [5]. Within this presentation, we will discuss design considerations, future steps, and possible fields of applications.
Results & Conclusions	We plan to develop a tunable aerosol generator for synthetic reference aerosol mixtures that mimic real ambient aerosols. The EMPIR-AeroTox research project will focus on the health effects of atmospheric particles. However, the application of such a device can be extended to different research disciplines. For instance, thanks to their controlled and tunable properties these lab-generated particles have the potential to serve as reference aerosols to challenge common field instruments [5], such as aethalometers, photoacoustic sensors, or aerosol mass spectrometers in order to understand artifacts and measurement uncertainties. This work is part of the AeroTox project funded by the European Union

	through the European Metrology Programme for Innovation and Research (EMPIR). We gratefully acknowledge the funding of the pilot study by the Swiss Federal Office for the Environment.

	Khan M. Yusuf
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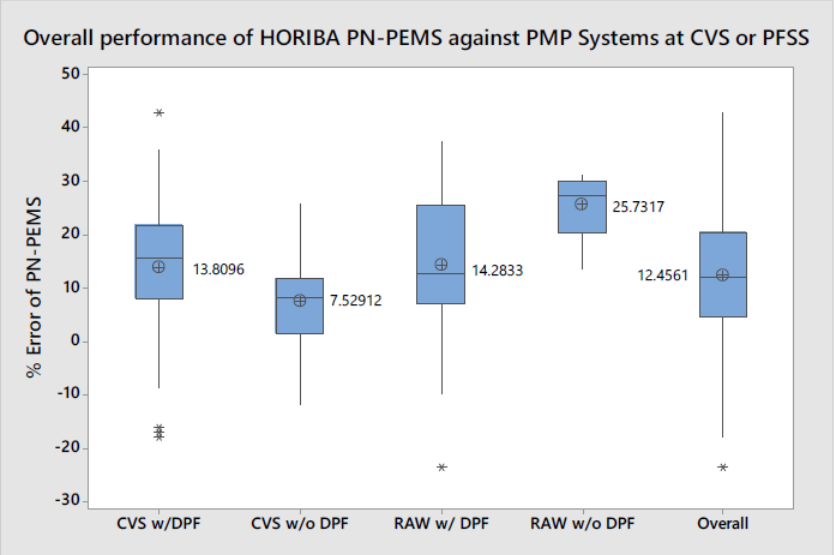
Publication title	Evaluation of Horiba PN-PEMS against PMP based PN systems for Heavy Duty diesel Engines
Publication type	Poster
Introduction & Background	Euro VI regulations require Particle number (PN) measurement for engine certification as well as in-use conformity. PN-PEMS developed for in-use testing are conceptually like PN instruments (AVL Particle Counter, Horiba SPCS etc.) for laboratory testing which are based on PMP protocol. The only difference is that PN-PEMS are allowed to have corona discharger for counting particles in addition to condensation particle counter (CPC). Recent studies have shown up to ±50% difference for corona discharger based PN-PEMS and but much better correlation with the CPC based PN-PEMS. Thus, Cummins selected CPC based Horiba OBS-ONE PN-PEMS for demo at Cummins Technical Center, Indiana where it has been evaluated against different units of AVL Particle Counter at CVS and RAW sampling locations.
Methodology	This study is divided in three phases. In the first phase, Particle numbers were measured from the same location at the Constant volume sampling (CVS) tunnel. For this, Cummins 6.7 L, 10 L and 13 L engines are being used. Brake-specific Particle Number (BSPN) levels of 1010-11 and 1013 were generated by selecting Cummins engines equipped with DPF or without DPF in aftertreatment systems. In the second phase of this study, PN-PEMS will measure from the raw location and AVL 489 will measure from partial dilution flow systems. In the third phase, data will be shown from the chassis dyno testing between various PN-PEMS and PMP system.
Results & Conclusions	Horiba PN-PEMS reported ~19% lower BSPN on an average from 60 various test cycles for the PN levels of 1010-11. This data also showed the ability of the PN-PEMS to accurately report BSPN at lower levels which has been an issue with corona discharge based PN-PEMS. In case of engine out BSPN levels (1013), PN-PEMS on an average reported 10% lower than AVL 489 units. The short-term repeatability and reproducibility of the PN-PEMS was also evaluated with the non-DPF engine and would be reported in the presentation.
Images	

Caption Figure 1:	 Overall performance of HORIBA PN-PEMS against PMP systems at CVS or PFSS

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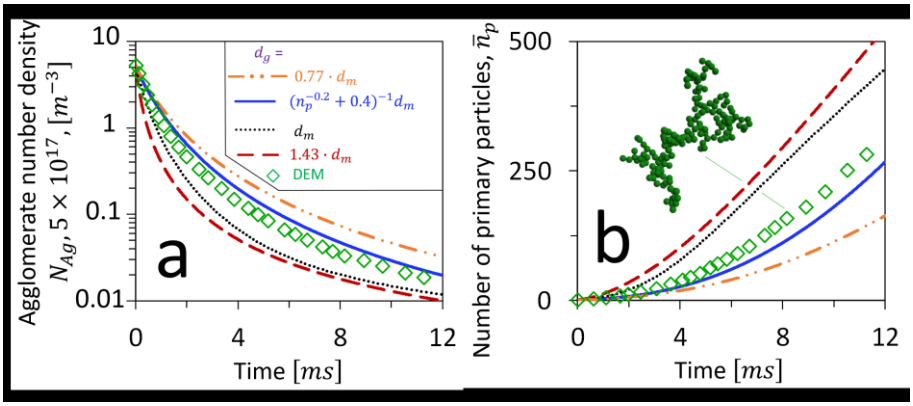
Coauthors	G. A. Kelesidis;S.E. Pratsinis
Publication title	Simplified Coagulation Dynamics of Agglomerates @ Self-Preservation
Publication type	Poster
Introduction & Background	Agglomerate particle morphology and concentration play important roles in optical diagnostics for nanoparticle processing and pollution control. Following particle dynamics with mesoscale simulations or multi-sectional population balance models is computationally expensive and cannot be used routinely for large-scale simulations. Monodisperse population balance models are computationally affordable and easy to use. However, they apply best when particles have attained their self-preserving size distribution (SPSD) and asymptotic fractal-like structure by coagulation, a condition that can be readily attained when high particle number concentrations are involved. In such condition, monodisperse models can accurately simulate aerosol dynamics if particle morphology and coagulation frequency are predicted well.
Methodology	Here, we present a monodisperse model for aerosol dynamics by coagulation in the absence of nucleation, surface growth and sintering. The model only solves one differential equation that tracks number density of the agglomerates, N_Ag made of spherical primary particles and then calculates average number of primary particles per agglomerate, ⟨n_p ⟩, mobility, ⟨d_m ⟩, and gyration, ⟨d_g ⟩, diameters using scaling laws derived from mesoscale discrete element modeling (DEM) simulations [Kelesidis, G. A., Goudeli, R., Pratsinis, S. E., (2017) Carbon, 121, 527]. DEM driven enhancement factor arising from the SPSD of agglomerates in the free molecular regime is used also in the particle collision frequency function to account for the effects of polydispersity in agglomerate size on particle dynamics and morphology [Goudeli, E., Eggersdorfer, M. L., & Pratsinis, S. E. (2016). Langmuir, 32, 9276]. We investigate the importance of scaling laws for agglomerate morphology on the performance of the monodisperse model by comparing different relations for normalized mobility, d_m⁄d_p and gyration, d_g⁄d_m , diameters.
Results & Conclusions	The monodisperse model predicts particle number concentrations during agglomeration in the free molecular regime within 35% of detailed mesoscale simulations when it uses DEM derived scaling laws for particle morphology and an enhanced collision frequency due to the polydispersity of the particles as shown in Figure 1a. Using DEM derived scaling laws for particle morphology as well as accounting for enhanced collision frequency due to polydispersity in particle size enables accurate prediction of number of primary particle per agglomerate shown in Figure 1b.
Images	

Caption Figure 1:



Evolution of a) total number density of the agglomerates, N_Ag and b) average number of primary particles per agglomerate, n_p as a function of time during agglomeration from DEM (diamonds) compared to PBM (lines) simulations using different relations for d_m⁄d_g.

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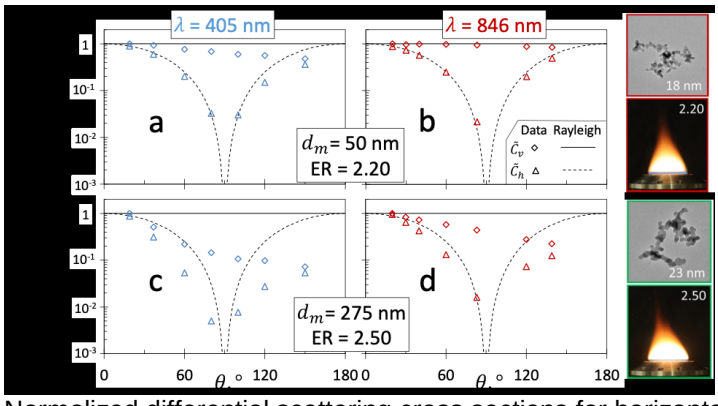
Publication title	Soot Optical Properties in Premixed Flames
Publication type	Poster
Introduction & Background	Light scattered from soot nanoparticles impacts atmospheric visibility as well as radiative balance. Optical fire sensors rely on light scattering for selective detection of soot emissions from fires. Soot nanoparticles are ramified agglomerates of several primary particles. The agglomerate morphology and primary particle size significantly affect light scattered from soot nanoparticles. However, agglomerate morphology is often ignored for interpretation of light scattering data.
Methodology	Here, the differential scattering cross section of soot nanoparticles generated from ethylene premixed flames are investigated by a multi angle scattering chamber at red (846 nm) and blue (405 nm). Particles are rapidly diluted and size selected based on their mobility diameter using a differential mobility analyzer and their differential scattering cross sections for horizontal and vertical light polarizations are measured. Agglomerate mass is measured with an aerosol particle mass analyzer and primary particle diameters are measured from transmission electron microscope images. Average diameter of soot primary particles is increased from 9 to 18 and 23 nm by changing the flame equivalence ratio, from 2.05 to 2.2 and 2.5, respectively. Soot agglomerates ranging from 30 to 275 nm in mobility are sampled from 5 cm above the burner at high enough concentrations for reliable scattering measurements.
Results & Conclusions	Increasing agglomerate size or decreasing the wavelength of incident light increase the size factor, and the differences between normalized differential cross sections for forward and backward scattering as shown in Figure 1. Agglomerates with mobility diameters less than 50 nm follow Rayleigh scattering as shown in Figure 1b. Agglomerate with larger mobility diameters have smaller effective densities and are more porous. Higher porosity increases trapping of the scattered light and results in a deviation from Rayleigh scattering regime.
Caption Figure 1:	 Normalized differential scattering cross sections for horizontal () and vertical () light polarizations for soot agglomerates with different mobility diameters sampled from ethylene premixed flames with equivalence rations of a & b) 2.2 and c & d) 2.5.

	Koch Sergej
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Publication title	reactivity of particles from gasoline direct injection engine
Publication type	Poster
Introduction & Background	With the introduction of the European emissions legislation for particle number and particle mass (Euro 6c stage), particulate emissions are currently a core issue in the development of Gasoline Direct Injection (GDI) engines. Due to the different mixing process of fuel and air GDI engines emit more particulates than engines with port fuel injection. Even at low mass concentrations fine and ultrafine particles may penatrate into the lung with adverse effects on health . The present development aims at the reduction of particulate emissions through exhaust gas aftertreatment, e.g. via gasoline particle filters (GPF). To minimize the technical complexity in the aftertreatment system the control of the burn-out of particulates within GPF has an enormous significance. The regeneration behavior of GPF is essentially dependent on the reactivity of the stored soot and its properties that in turn depend on the engine operation conditions. The main objective is the enhancement and control of the reactivity of the emitted soot particles by engine parameters.
Methodology	The basic studies were carried out on a turbocharged 4-cylinder engine with direct injection by varying the engine operating parameters, e.g. engine speed, air fuel ratio, injection timing. The particles are investigated in terms of their reactivity, number and size distribution and microstructure by using thermogravimetric analysis (TGA-FTIR), engine exhaust particle sizer (EEPS) and high-resolution transmission electron microscopy (HR-TEM).
Results & Conclusions	The investigations show a direct and indirect impact of engine operation parameters on the soot reactivity and its properties. The results of the parameter variations showed that the reactivity of particles can be controlled and enhanced by the operation conditions of the engine. To maximize the soot reactivity further investigations must be performed

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Publication title	**Real-time measurements of cost-efficient filter solutions for small construction machines**
Publication type	Poster
Introduction & Background	In 2019 new and tightened European emission standards for new, smaller non-road mobile machinery (NRMM) has become effective, the so-called Stage V standards. This is expected to give rise to more stringent demands from contractors and public authorities to already existing NRMMs. To accommodate this new retrofit exhaust gas purification systems are developed, implemented and tested in a new Danish EPA supported project by Danish filter and catalyst-company Purefi A/S, Danish Technological Institute and leading Danish contracting company, Per Aarsleff A/S. The project has a high focus on developing simple and cost-effective solutions for smaller, older construction machines. Hence, rendering it profitable to install on current machines, rather than discarding these machines and replacing them with entirely new ones. These new solutions will entail improved air quality on construction sites and in the immediate environment in urban areas.
Methodology	The efficiency of the retrofit emission system has been tested on a representative compact excavator by direct measurement in the exhaust gas with and without the system installed. Numerous parameters are investigated, including NOx and CO2 emissions (by portable emission measurement system), particle number concentration and size distribution (scanning mobility particle sizer). Additionally, ambient measurement assessing the surrounding air quality have been conducted (Condensation Particle Counter, dust monitor and portable nanoparticle analyzer). Three different types of exhaust gas purification systems will be implemented and tested during this project. The solutions consist of either a particle filter or a combined particle filter and NOx-reducing SCR catalyst.
Results & Conclusions	Initial test of a particle filter and SCR-catalyst emission-system has demonstrated a reduction in particle number concentration of more than 99% and a reduction of NOx-concentrations between 55% and 95% depending on engine load. Furthermore, ambient measurements in the surroundings have shown particle number concentration unaffected by the operating excavator, hence demonstrating an extremely efficient exhaust gas purification system. Prospectively, simpler solutions will be implemented and tested to identify the most cost-effective solution suitable for this type of application.

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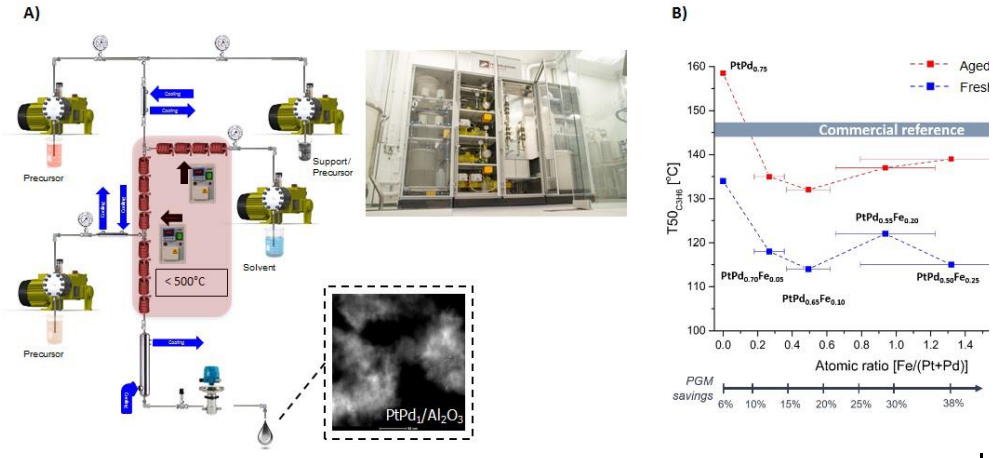
Coauthors	Patricia Hernández-Fernández: Hugo J. L. Silva: Leif H. Christensen: Christian Kallesøe
Publication title	Production of fine-tuned nano-catalysts for exhaust emission treatment: The potential of supercritical flow synthesis
Publication type	Poster
Introduction & Background	New engine technologies, tighter emission regulations, and fluctuating precious metals prices are creating tremendous challenges for the automotive industry. For instance, higher requirements for the removal of pollutants such as hydrocarbons, carbon monoxide, and soot particles from the exhaust, must be met. We present an unconventional continuous flow synthesis method to produce catalytic nanomaterials utilizing supercritical fluids. This method was used to prepare highly active and hydrothermally stable catalysts for diesel and petrol exhaust gas treatment, taking advantage of the supercritical fluid properties for a continuous production of finely divided nanoparticles with narrow size distribution and high crystallinity.
Methodology	In this work, continuous supercritical flow technology, fig. 1A, was used to prepare various nanoparticle structures for catalytic converters. Supercritical flow technology is an emerging synthesis process, relaying on the high pressure and temperature conditions of the solvent, above the critical point. Supercritical fluids have attracted great attention as environmentally friendly solvents for chemical processing and share properties from gaseous and liquid phases, offering the opportunity to manipulate different media properties such as density, viscosity and diffusivity by controlling the pressure and temperature. Furthermore, they enable a fast nucleation reaction (tens of a second) making it attractive as a continuous method. Our developed flow reactors have a high control of process parameters, such as temperature, pressure and flow rates, making it possible to tune the crystalline phases, particle sizes and atomic ratios of the nanoparticles. Furthermore, our reactors facilitate the synthesis of particles directly onto supports, such as carbon or oxides. This makes it suitable for a one step production of both Pt group metal-(PGM) and oxide-based catalysts, with production rate up to 0.5 kg/h [1], minimizing waste of material during the fabrication process. Reference: [1] WO 2014005598-A1 / WO 2015104025-A1
Results & Conclusions	Supercritical flow technology was used for a one step production of PtPd and PtPdFe nanoparticles supported on high surface area γ-Al2O3 for diesel oxidation and soot combustion purposes. The temperature of half conversion (T50) for propene oxidation used as a probe reaction was measured for synthesized PtPd/γ-Al2O3 and compared to a commercial reference of the same material, fig. 1B. The synthesized PtPd/γ-Al2O3 exhibits a better performance both as fresh and after hydrothermal ageing at 750 °C (10% O2, 10 % H2O) compared to the reference. Introducing Fe into the structure, results in a further increase in activity, both as fresh and aged, due to the strain effect. Further, the addition of Fe decreases the sintering of the PGM particles creating a more stable catalyst with the potential of saving up to 38 wt.% of PGM without compromising the performance. The supercritical flow technology is also suitable for the preparation of mixed oxides with high crystallinity and stability. We have successfully synthesized

	Ceria-Zirconia, doped with Lanthania, Praseodymia, Ytria, Neodymia, etc., used as washcoat in three-way catalysts for e.g. petrol engines. The surface area of our materials is higher than 50 m2/g after aging at 1000°C, corresponding to state-of-the-art [2]. Furthermore, the oxygen storage capacity reaches values of more than 300 µmolO2/gr at 500 °C. Reference: [2] E. Rohart, O. Larcher, S. Deutsch, C Héduin, H. Aïmin, F. Fajardie, M. Allain, P. Macaudière, Top. Catal. 2004, 30/31, 417-423.
Images	
Caption Figure 1:	 Figure 1. A: Scheme and view of the up-scaled reactor at DTI. B: Summary activity results of PtPd/ɣ-Al2O3 with different Fe loadings catalyst for propene oxidation, as fresh and after hydrothermal aging (750^{0}C/3h, 10% O2, 10% H2O).

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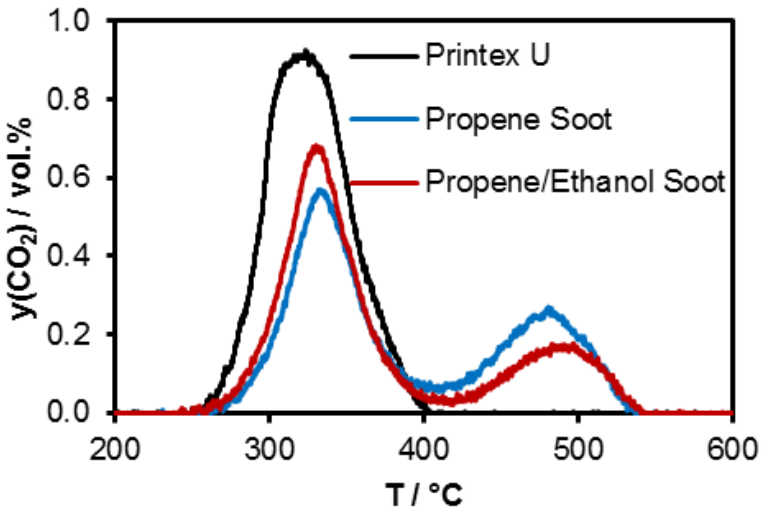
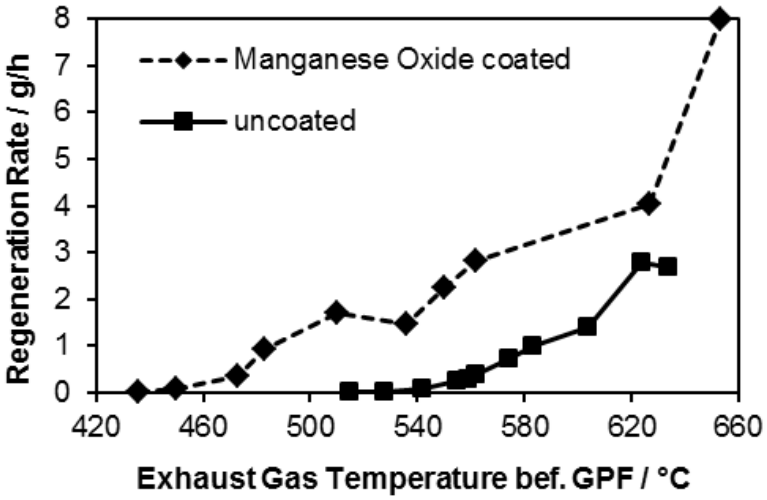
Coauthors	Christian Singer; Kai Kettenring (OPEL/GM)
Publication title	Soot Oxidation on Manganese Oxide Catalysts in Gasoline Exhaust
Publication type	Poster
Introduction & Background	Gasoline engines with direct fuel injection (GDI) reveal high efficiency directly resulting in reduced output of CO2. However, due to tightening of emission limits the output of soot even from GDI engines comes more and more under pressure. Consequently, gasoline particulate filters (GPF) with passive regeneration have been introduced. The present paper therefore addresses the development of MnOx catalysts for oxidation of soot by O2 in GPF systems. Manganese oxide catalysts were reported to be active for oxidation of hydrocarbons and soot in excess of oxygen [1]. Additionally, MnOx made by flame spray pyrolysis (FSP) was shown as one of the most efficient soot oxidation catalysts reported so far [2].
Methodology	Catalytic tests were performed by temperature programmed oxidation (TPO) using tightly contacted powder mixtures of different MnOx catalysts with model soot (Printex U) as well as propene and propene/ethanol carbon black mimicking (biogenic) gasoline soot. For mechanistic investigations, isotopic TPO studies with 18O2 were also made by systematically varying the oxygen content. Furthermore, for practical evaluation, the FSP catalyst was coated onto cordierite-type GPF substrates (4.66 x 4.72”, 20 g/l) and was investigated in the exhaust of a stoichiometric GDI engine under stationary and transient conditions. Filter regeneration was checked by a test procedure performed in the GDI engine exhaust at steady state.
Results & Conclusions	The TPO studies confirmed the pronounced soot oxidation activity of FSP-MnOx with complete soot combustion already at 250°C, even under gasoline exhaust conditions. Isotopic TPO of FSP-MnOx/soot suggested transfer of oxygen from surface and bulk of catalyst to soot by physical contact points. A scarcity of gas-phase O2 leads to an increasing participation of bulk oxygen. Consequently, in excess of oxygen vacancies are refilled by O2. The tests of FSP catalyst with propene and propene/ethanol soot (Fig 1) showed that catalytic activity is not clearly affected by physical-chemical properties of the soot, e.g. the number of oxygen compounds present on soot surface, due to the outstanding oxidation activity of the catalyst including very fast oxygen transport to the soot. The results of the engine tests (Fig 2) illustrated that particle emissions can be readily reduced with the use of the MnOx-coated coated GPF lowering the initial temperature of the soot oxidation (T≈450 °C) by approximately 100 K as compared to a GPF reference without catalytic coating. Consequently, regeneration of the catalytic GPF can be achieved by real driving scenarios. In summary, the transfer from laboratory scale to real GPF substrates evidences that FSP-MnOx catalyst reveal outstanding efficiency in soot oxidation under gasoline exhaust conditions. Furthermore, biogenic fuel components such as ethanol hardly affect the catalytic soot oxidation as referred to industrial Printex U model soot. Finally, FSP-MnOx represents one of the best soot oxidation catalysts and is therefore a promising candidate for the application in gasoline particulate filter systems.-
Images	

Caption Figure 1:	 TPO study of tight contact mixtures of FSP-Mn2O3 with Printex U, ethanol and propene/ethanol soot under gasoline conditions: y(O2)=1 %, y(H2O)=2 %, N2 balance.
Caption Figure 2:	 Regeneration of the MnOx-coated (20g/l) and uncoated GPF after soot loading (ca. 2.2 g/l) at 3600 rpm, SOI 350°CA b. TDC, λ=1, t=12 min. Regeneration at steady state lean operation (λ=1.2) for 30 min.

	La Rocca Antonio
Affiliation	The University of Nottingham
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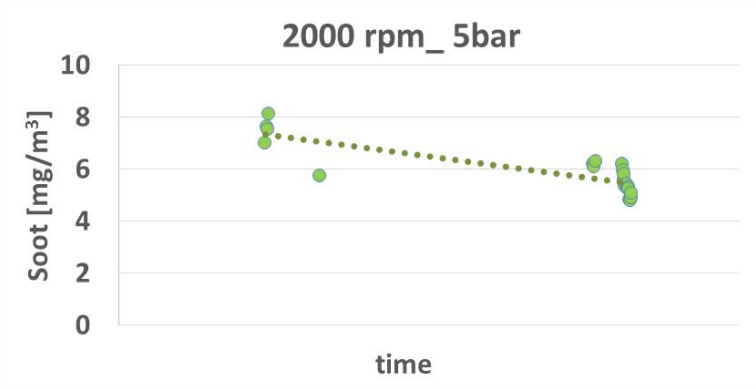
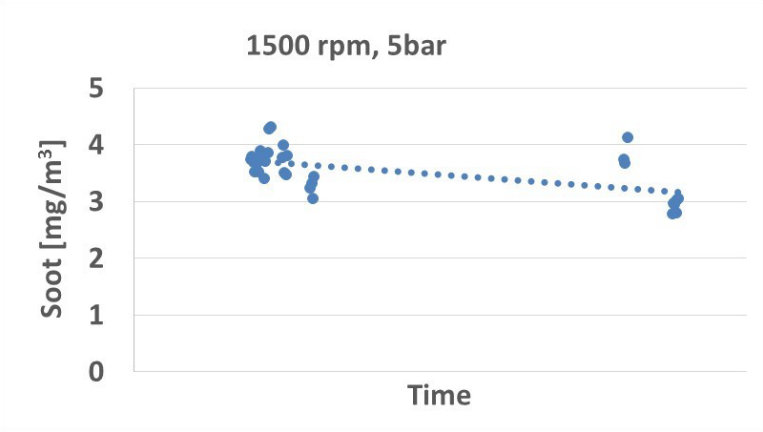
Coauthors	Andrea Pacino; Taufik Yuwono
Publication title	Copper leaching from the fuel line of a HPCR DI diesel engines and its effect on combustion characteristics and particulate emissions
Publication type	Poster
Introduction & Background	Several investigations available in the literature have shown that metallic additives can have a positive effect on engine combustion and emission reduction [1]. However, if used in conjunction with particulate filters, secondary emission may form [2]. The presence of particles in the fuel can also be associated to the interaction between fuel and Fuel Injection Equipment. Corrosion behaviour of aluminium, copper and stainless steel in diesel has been investigated and their effect on fuel properties has been quantified [3]. But despite the catalytic activity of metallic-based fuel additives has been investigated widely, the effect of fuel contamination by metal leaching on emissions and combustion characteristic has not.
Methodology	In this work, the leaching of metals from a helicoidally shaped copper duct installed along the low pressure fuel line of a HPCR DI 2.2 Diesel engine was investigated. Metal concentration in the diesel fuel was measured using inductively coupled plasma – optical emission spectrometry (ICP). The fully instrumented engine was run at a constant engine speed of 1500 and 2000rpm and at a constant load of 5bar BMEP. A pilot plus main strategy was used. Fuel tank was filled with diesel fuel having a copper content less than 0.01mg/kg. Experiments were carried out over two days. Fuel samples were collected at end of each day of testing. The experimentally acquired in-cylinder pressure data was used to investigate combustion characteristics. An AVL Smoke Meter was used to measure the soot concentration emitted by the diesel engine.
Results & Conclusions	A fuel flow meter installed before the HP fuel pump measured a flow rate of around 33kg/h through the helicoidally shaped copper duct while only 3-4kg/h were injected into the four cylinders; the remainder is recirculated into the fuel tank. ICP analysis showed an average rate of copper release of 0.012mg/kg.h in the diesel. At the end of the last day, of testing, the total copper concentration accumulated in the fuel tank was 0.19mg/kg. Soot emission decreases as copper concentration increases. A maximum reduction of 27% was measured across the two days for the 2000rpm 5bar case, Figure1; while a 14.6% reduction was measured for the 1500rpm 5bar case, as shown in Figure 2. As reported in the literature, metallic additives act as catalysts for the combustion process and for promoting oxidation of carbon nanoparticles formed during combustion. The heat release was investigated to understand the reasons behind the measured soot reduction. The fuel starts to combust shortly after fuel from main injection enters the combustion chamber, but there is no change in the ignition delay. This suggests that physical/chemical delay and fuel/air mixture preparation before ignition are not the reasons of soot reduction; while it is rather the catalytic effect of the leached copper that promoted soot oxidation. A slightly shorter CA50 was also noticed when copper contaminated fuel is combusted. What is still unclear is the size distribution of the copper nanoparticles in the dispersion and whether this is stable over time. Moreover, further investigation is needed to understand impact of copper on the secondary emissions when a particulate filter is used and whether a minimum permissible dose of copper can be defined.
Images	

Caption Figure 1:	 Figure 1. Average soot concentration measurements. Test operating condition 2000rpm and 5 bar BMEP.
Caption Figure 2:	 Figure 2. Average soot concentration measurements. Test operating condition 1500rpm and 5 bar BMEP.

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Publication title	Exposure of Heavy Metals and Poly Aromatic Hydrocarbons in Indoor Environment: Assessing health Impacts in Lucknow
Publication type	Poster
Introduction & Background	Indoor Air Quality (IAQ) at residential areas has become an issue of public concern. Growing population, urbanization, lack of awareness and limited research in this region of world is leading the human raze to jeopardize.Many recent Governmental policy interventions have been undertaken to lessen ambient air pollution, but very little is known Roadside and Livestock. PAHs were collected using XAD-2 resin tubes (600 mg) for gaseous phase PAHs and PTFE filter paper (37 µm dia) for particulate phase. The about IAQ. The present study was conducted in Lucknow city, according to WHO which ranks among top ten most polluted cities of the world. Pollution related studies in the region mainly emphasize on monitoring ambient PM2.5 at only few locations.
Methodology	In order to know current status of IAQ and its' effects, sixteen urban houses were selected for monitoring PM10, PM2.5 and 16 poly aromatic hydrocarbons (PAHs) listed as priority pollutants by the U.S. EPA for a span of one year (March 2015 to Feb 2016). These houses were characterized in four different microenvironments viz. Well planned,Denselypopulated, individual PAHs were identified using a gas chromatograph with mass spectrometry detector (GC/MS).Seven heavy metals viz. Fe, Zn, Cu, Pb, Mn, Ni and Cr were also analyzed in PM10 samples. Analysis was done through Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer, Analyst 100).
Results & Conclusions	The concentration (µg/m3) of PM10 and PM2.5 for 24 hours' average were 92 and 59 for well planned, 187 and 114 for densely populated, 210 and 156.4 for roadside and 164 and 108.42 for livestock microenvironments respectively. These values were much higher than the WHO limits, being highest for roadside microenvironment.The concentrations of heavy metals in all four microenvironments were found to be in the following order- Well planned microenvironment- Fe > Zn >Pb> Cr > Ni > Cu >Mn, Densely populated microenvironment- Fe > Cr > Zn >Pb> Ni > Cu >Mn, Roadside microenvironment- Fe >Pb> Zn > Cr > Ni > Cu >Mn, Livestock microenvironment- Fe> Cr> Zn>Pb> Ni> Cu>Mn. The mean concentration of total 16 PAHs (∑ PAHs) at different microenvironmentswas determined and found maximum at roadside houses viz. 34.1, 19.3, 57.4 ng/m3 in summer, monsoon and winter seasons respectively. Among these 16 PAHs, Benzo (a) Pyrene (BaP) is believed to be most carcinogenic and was found to be highest in roadside residences with mean concentration in summer, monsoon and winter viz. 3.6, 5.3 and 7.1 ng/m3 respectively.Univariate Pearson correlations were determined by using SPSS 11 to find correlations among heavy metals in order to find common sources of these metals. The main sources influencing the concentrations of the heavy metals associated with PM10 samples was done through varimax rotated factor analysis. Calculation of Enrichment Factors was done for heavy metals associated with particulate matter to identify their source. Health problems related to respiratory system and irritation in the eyes were more prevalent. There is limited knowledge on association of a disease with inhalation exposure, mainly in indoor environment. The issue needs more focus to understand the mechanisms ofdamage and to propose measures to control the emissions, decrease the exposure and its adverse effects. This study was done in order to provide useful information to help understand the usually ignored and continuously deteriorating IAQ in Lucknow, India and thereby contribute towards and improved strategy to frame robust policy making at National and International level.

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Publication title	A Theoretical Study of PAHs Growth by Phenylacetylene Addition
Publication type	Poster
Introduction & Background	Polycyclic aromatic hydrocarbons (PAHs), known as soot precursors, are quite abundant in the universe, and exert great influence on the environment and human beings. In hydrocarbon combustion, the formation of PAHs involves both chemical reactions and physical processes. Numerous experimental and theoretical studies describe the mechanism and pathways of PAH growth and soot inception. The hydrogen-abstraction/acetylene-addition (HACA) mechanism is a widely accepted mechanisms for PAH growth, and it is the framework of most of the current PAHs reaction mechanisms. However, several researches have revealed that the production of PAHs are underestimated via HACA pathways [1-3]. Experiments show that phenylacetylene (C6H5C2H) is abundant in flames [4-6] since it is easily formed from phenyl radical by C2H2 addition. The aim of this work is to systematically explore PAHs growth by the addition of C6H5C2H without the consideration of other carbon sources (i.e. acetylene). The potential energy surfaces and reaction rate coefficients of this reaction system are obtained at different levels, and the yields of all products are calculated and compared with a HACA mechanism.
Methodology	In this work, the structures of all species including minima and transition states were optimized using density functional theory (DFT) with B3LYP hybrid functional 6-311+G(d,p) basis set. The sums of electronic and zero-point energies were refined with CBS-QB3 method. Gaussian 09 program package with the version of D.01 was applied to calculate all the quantum calculations. The reaction rate coefficients were calculated using conventional Transition State Theory (TST) in the temperature range of 500-2500 K. RRKM theory was conducted to illustrate the pressure dependence. To simulate the yield distributions of various PAH products, a closed zero-dimensional batch reactor in Chemkin-Pro software was used to calculate the C6H5C2H-C2H2-H-Ar reaction system, with the mole fractions of the initial reactants referred to a premixed ethylene flame studied in [3].
Results & Conclusions	The results prove that it is feasible for the PAH growth by phenylacetylene (C6H5C2H) addition. The recombination reactions of C6H5C2H can produce PAHs with 2, 3, and 4 rings. This reaction network is pressure-independent but highly temperature-dependent. Taken our C6H5C2H reaction network into consideration, it is more efficient to generate PAHs compared to HACA mechanism, especially large PAHs with 3 and 4 rings, which subsequently increases the formation of soot particles. Based on the yield analysis of all products, PAHs with 5-member ring are quite important in this reaction system, since most of the 4-ring PAHs containing one or two 5-member ring in their molecules.

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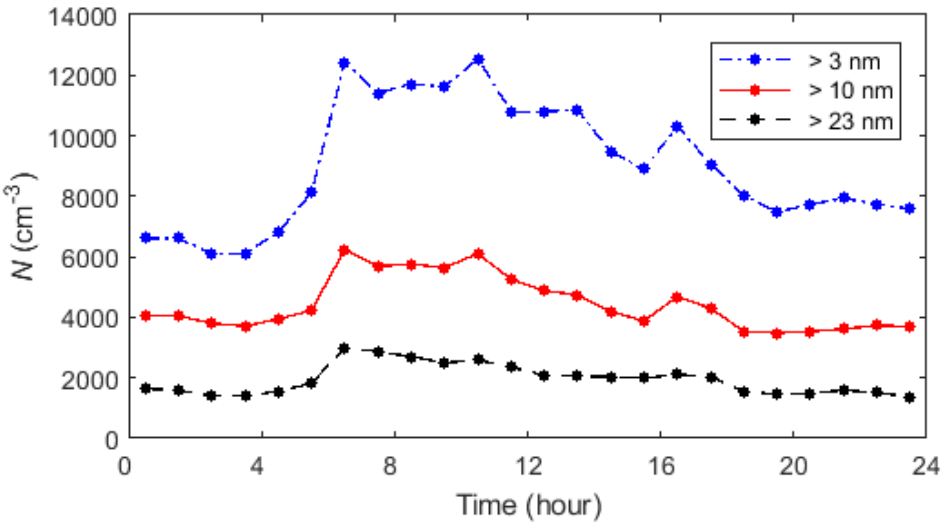
Publication title	Non-volatile sub-23 nm particle concentrations in a busy street canyon
Publication type	Poster
Introduction & Background	The European Union legislation limiting the number of solid particles emitted by vehicles follows Particle Measurement Program (PMP) protocol that takes into account only particles above 23 nm in size (Giechaskiel et al., 2014). Even though sub-23 nm emission particles are in many cases known to be volatile, also non-volatile particles have been observed in this size range (e.g. Kittelson et al., 2006; Mayer et al., 2010). In addition, it has been found that the size range of traffic emitted particles extends even down to 1-3 nm (Rönkkö et al., 2017). In this study, we measured the number concentration of non-volatile sub-23 nm particles in a busy street canyon. In order to evaluate the results more thoroughly, the number concentration of non-volatile > 23 nm particles was also measured.
Methodology	Measurements were carried out at an urban supersite measurement station operated by Helsinki Region Environmental Services (HSY) in May 2018. The station was located on the pavement along a relatively busy street leading toward the city centre of Helsinki, Finland. The traffic rate of the road is ~28,100 vehicles/day of which the heavy-duty vehicles account for 12 %. Particle number concentrations were measured using a Condensation Particle Counter Battery (CPCB) provided by Airmodus Oy. The CPCB consisted of a combination of a Particle Size Magnifier (PSM) and a Condensation Particle Counter (CPC) in parallel with three CPCs with different cut-off sizes. Hence, total particle number concentrations were simultaneously measured for size ranges > 23 nm, > 10 nm, > 3 nm, and > 1.4 nm with a time resolution of one second. The aerosol sample was taken from the roof of the station and led to the CPCB through a PMP-like system. Sample line included a hot ejector diluter in which the sample was heated to 300 ºC. Hot diluter was followed by another ejector diluter operating in room temperature. During the campaign, also other measurements were conducted at the station. For instance, simultaneous CO2 measurement data was used in the evaluation of the emission factors.
Results & Conclusions	According to preliminary results, the highest concentrations of non-volatile particles were measured between 6-11 a.m. on workdays (Fig.1). This time frame corresponds to morning rush hour and typical driving hours for heavy-duty vehicles. A smaller rush hour peak was detected in the afternoon when the traffic congestion was more dominant on the other side of the street. The CPCB was found to be an advantageous measurement tool for counting small particles at the roadside as the concentration and particle size may be highly variable.

	In the size range of 3-23 nm, emission factor for non-volatile particle number was 4.5·10^14 (kgfuel)^(-1) and for all particles 2.8·10^15 (kgfuel)^(-1). Emission factors for > 23 nm particles were 1.4·10^14 (kgfuel)^(-1) for non-volatile and 2.3·10^14 (kgfuel)^(-1) for all particles. These observations suggest that a considerable amount of non-volatile sub-23 nm particles exist in a street canyon environment. In addition, the results indicate that the traffic may be a major source of non-volatile sub-23 nm particles in urban areas. This work was made in the AJOKKI project funded by HSY and the CITYZER project funded by Business Finland, HSY and Pegasor Oy. Giechaskiel, B., Manfredi, U., & Martini, G. (2014) SAE Int. J. Fuels Lubr. 7(3):2014. Kittelson, D., Watts, W. & Johnson, J. (2006). Journal of Aerosol Science, 37(8), 913 – 930. Mayer, A. C. et al. (2010). SAE Technical Paper 2010-01-0792 Rönkkö, T. et al. (2017). PNAS, 114(29), 7549-7554.
Images	
Caption Figure 1:	 Average diurnal variation of non-volatile particle number concentrations in a street canyon during workdays in May 2018.

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Affiliation	Kaust University
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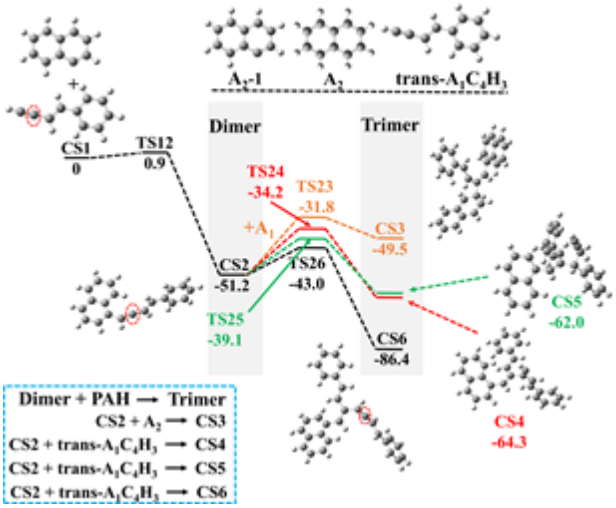
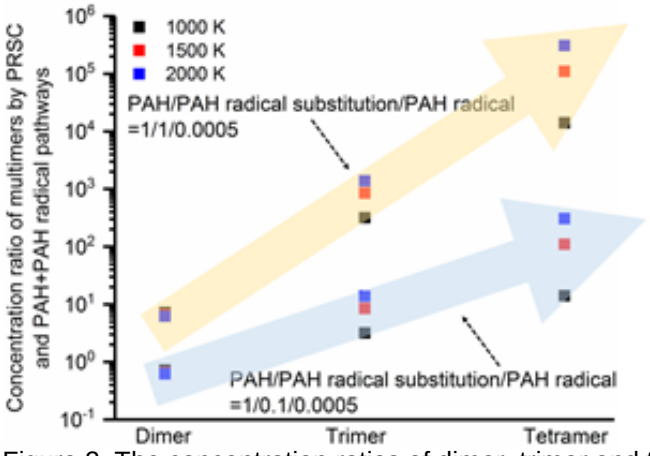
Coauthors	Peng Liu, Zepeng, Li, Anthony,
Publication title	Soot nucleation triggered by PAH with vinyl radical substitution
Publication type	Poster
Introduction & Background	Soot produced in incomplete combustion of hydrocarbon has received increasing interest in areas such as nanoparticle material synthesis, engine emissions, global climate affects, human health, and astronomy science. Evidences show that the climate can be altered by atmospheric soot, due to its radiation characteristic and cloud condensation nuclei ability. Exposure to ultrafine soot particles bonded with polycyclic aromatic hydrocarbon (PAH) in ambient air increases the risk of lung and skin cancers. In addition, understanding the formation of soot contributes to revealing the origin and evolution of carbonaceous interstellar particles, as they share similar formation processes. However, the formation mechanism of soot remains elusive, especially the soot inception process involving the transition from gas-phase hydrocarbon precursors to solid-phase soot particle. Numerous experimental and theoretical studies have shown that moderate-sized PAHs are the main precursors in the soot inception process. Currently, there are three conceptual pathways leading to soot inception from PAH. One hypothesis is that two pyrene molecules physically dimerize via van der Waals forces, but this pathway is refuted by the experimental study of Sabbah et al. where the dimer signal was not observed at temperatures above 200 K due to the weak binding energy. The formation of fullerene-like structures from very large PAH is an alternative hypothesis. However, the rate of this pathway is too low to capture the measured soot inception rate in various sooting flames. The chemical coalescence pathway seems the most promising solution to this scientific problem. Recently, Johansson et al proposed a rapid molecular clustering-reaction pathway involving the addition of PAH radical to resonance-stabilized radical species (like indenyl). In this pathway, the hydrocarbon precursor monomers are covalently bound, thus the formed covalently bound complexes are likely to survive at flame temperature. The molecular clustering-reaction pathway is robust in the region where radical species are abundant, but it may be weak in explaining the persistent inception and growth of soot in the post-flame region where radical concentration is too low to trigger the reaction. In addition, the application of this pathway may be limited due to the low concentration of resonance-stabilized radical species in some flames. Here, we present a novel soot inception and growth pathway driven by PAH with a vinyl radical substitution (named as PRSC for brevity), such as trans-1-phenylvinylacetylene (trans-A1C4H3). The PAH with vinyl radical substitution is a closed-shell structure, and abundant in various combustion conditions. In the proposed PRSC pathway, a dimer forms via the combination reaction of PAH radical and PAH with a vinyl radical substitution. The formation of a multimer or cluster can be persistently initiated by the PAH with radical substitution, without the requirement of any radical species. This makes the pathway preponderant not only in the main-reaction region, but also in the post-flame region. The thermodynamic, kinetic analysis, and recently reported experimental results greatly support the proposed PRSC pathway, when compared with other mechanisms involving radical species.
Methodology	ab initio calculation, reaction kinetic calculation and flame modelling
Results & Conclusions	The comparisons of the formation rate of PAH cluster including dimer, trimer, and tetramer between the typically PAH + PAH radical nucleation pathway and the proposed pathway were carried out. The results suggest that the proposed

	pathway is much more favored at various flame conditions, due to the high reaction rate, abundant reaction precursors, and non-requirement of radical species in growth process of carbonaceous multimer.
Images	
Caption Figure 1:	 Figure 1. Inception pathway driven by PAH with radical substitution, unit of energy is kcal/mol.
Caption Figure 2:	 Figure 2. The concentration ratios of dimer, trimer and tetramer formed by PRSC and PAH + PAH radical pathways.

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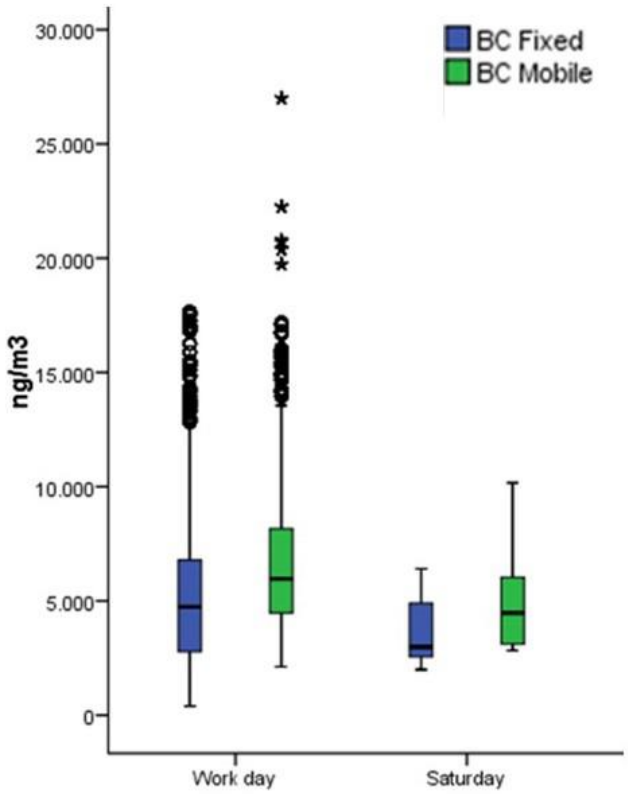
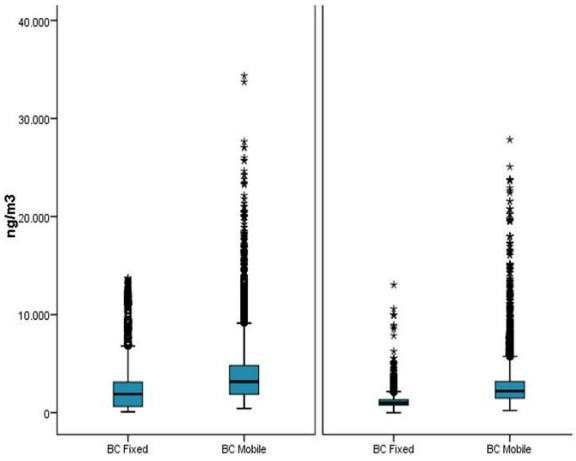
Publication title	Black carbon concentration levels along pedestrian routes in Milan
Publication type	Poster
Introduction & Background	High concentration levels of black carbon (BC), which have been linked to health problems, are typical for urban environments. In particular, BC is reported to be related to vehicular traffic emissions and is used as a tracer of primary anthropogenic emissions. In urban areas the spatial variability of BC concentration reflects changes in the strength of local sources and in atmospheric mixing. This latter can be strongly influenced by the features of the built environment, especially when the buildings flanking the streets on both sides create canyon-like environment, thus named urban canyons.
Methodology	In this work, BC concentration levels measured at high time and space resolution along pedestrian routes in Milan are reported. Two AE51 micro-aethalometers were used for field measurement of BC while walking the routes and, concurrently, at an urban background monitoring site. The field campaigns, covering both the winter and the summer period with two measurement sessions per day (morning and afternoon) during weekdays, were designed in order to investigate the spatial and temporal variability of the personal exposure concentrations to BC. Measurements have been performed along three pedestrian routes: a 17-km route in Milan city centre through six different urban zones, characterized by different traffic intensity and regulation (partially including the traffic congestion charge area); a 5-km route in the University campus area; a 20-km route still in the University campus area, but also extending towards the city centre and the outskirts of the city. Pedestrian routes were designed in order consider not only the different traffic intensity on urban roads but also the effect of the built environment on BC atmospheric dispersion.
Results & Conclusions	Seasonal results show that BC concentrations in the winter period were higher than in the summer. The highest concentrations were observed at the most traffic exposed sections of the routes; however, high concentration levels were also observed at urban canyon areas, though with reduced traffic. BC mean concentrations observed along the routes were higher than at the urban background site, suggesting that the concentrations measured at fixed monitoring stations may be a poor indicator of the real exposure in the urban environments.
Images	
Caption Figure 1:	



Workdays and Saturdays BC levels on the 17-km route (cold season data)

Caption Figure 2:



BC warm season levels on the 17-km route (left panel: morning data; right panel: afternoon data)

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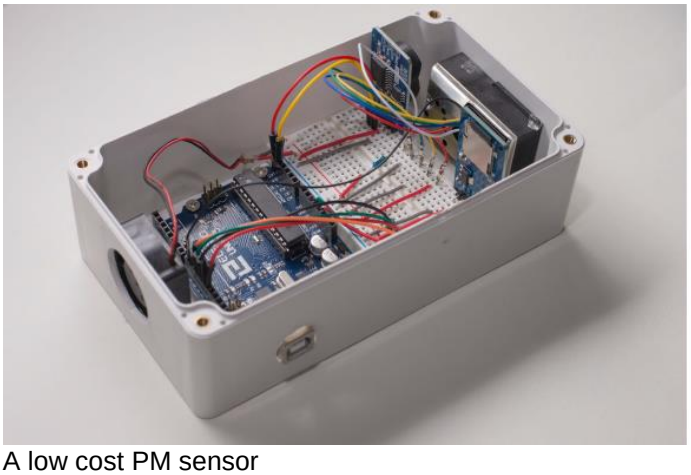
Publication title	Low cost PM sensors; are they suitable for measuring subtle particle variations in ambient or indoor air?
Publication type	Poster
Introduction & Background	Researchers are increasingly interested in the use of low-cost sensors to understand high resolution spatial distributions of PM; something where use of more expensive equipment is often less plausible. Currently many projects aim to develop these sensors to provide an appropriate way to supplement high quality fixed site data with lower quality high spatial distribution data. These low-cost particle sensors have been shown to correlate well with reference grade equipment (Wang et al., 2015). However, because of their relatively low sensitivities at low concentrations; there applications are often displayed in the context of measuring extremely high levels of pollution. For example, measuring in homes using solid fuels or in wood working shops. It is important to understand whether low cost particle sensors can be used to measure more subtle variations in PM; for example, those that may be experienced within a single residence or across a street canyon.
Methodology	This experiment utilised Sharp GP2Y1010AU0F and Shinyei PPD42NS low-cost particle sensors. They were firstly calibrated against reference grade equipment, and then deployed in the field. They were deployed in residences in Guangzhou as part of a larger campaign to understand how PM generated indoors moves through a residence, and how effective HEPA air purifiers are in combating indoor PM. The investigation aimed to determine whether these sensors were able to measure subtle variations in PM within indoor and outdoor environments in Guangzhou, China.
Results & Conclusions	Low cost PM sensors are of limited application in understanding subtle variations in indoor and ambient particulate matter.
Caption Figure 1:	 A low cost PM sensor

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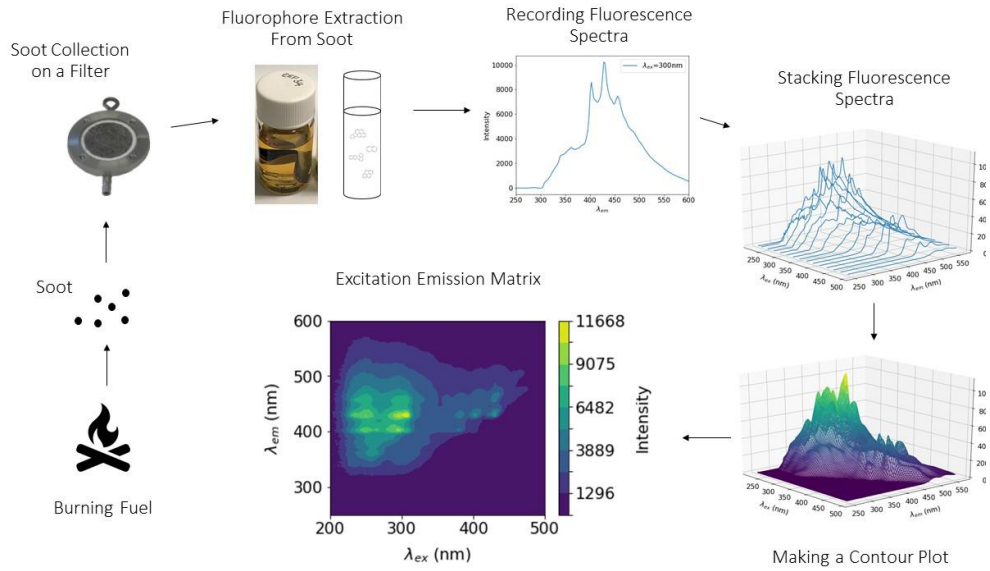
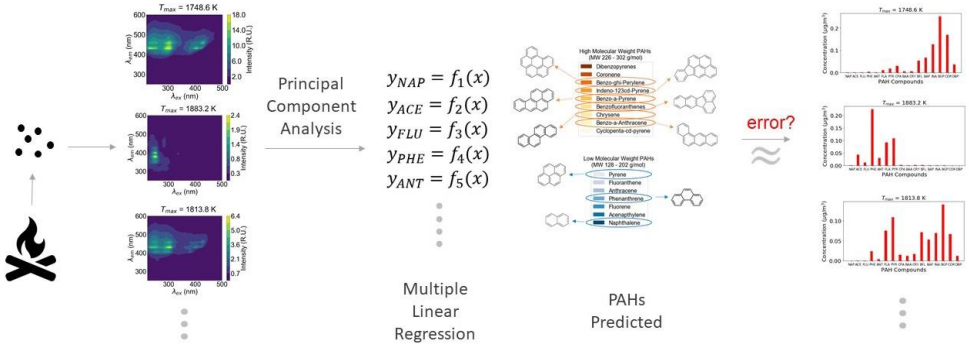
Publication title	Fluorescence Spectroscopy based Sensing of Combustion Generated Particulate Matter
Publication type	Poster
Introduction & Background	Ambient air pollution was responsible for 4.2 million deaths in the year 2016. Worldwide, ambient air pollution is estimated to cause about 16% of the lung cancer deaths, 25% of chronic obstructive pulmonary disease (COPD) deaths, about 17% of ischemic heart disease and stroke, and about 26% of respiratory infection deaths. The toxic potential of inhaled particles depends on their chemical composition. It is challenging for current exposure monitoring approaches to provide chemical analysis of the collected sample in the field settings. There is a need for robust approaches for analysis that can measure individual exposure to combustion generated particulate matter (PM). Ultimately, such improved assessment methods can enhance our understanding of the health effects of air pollutant mixtures, leading to an improved human health risk assessment and guidance. Polycylic Aromatic Hydrocarbons (PAHs), which are building blocks for combustion generated PM, are well-known carcinogens, mutagens and teratogens. Gas Chromatography Mass Spectrometry (GCMS) and Liquid Chromatography Mass Spectrometry (LCMS) are commonly used laboratory techniques to analyze PAH composition in PM. However, they involve PM collection on filters, followed by sohxlet extraction as pre-processing steps. Furthermore, instruments used for these standard laboratory analysis techniques are bulky and expensive. This makes offline laboratory analysis cumbersome. Hence, new technologies are being developed to complement the standard analysis techniques. Among these, fluorescence spectroscopy based techniques are relatively economical. Excitation Emission Matrix (EEM) analysis is a more systematic and powerful method among fluorescence based techniques as the multiple single-wavelength-excitations allow simultaneous determination of multiple fluorescent components.
Methodology	In this work, we use Principal Component Analysis (PCA) to decompose EEMs of PM samples generated from combustion of ethane and ethylene fuels in an Inverted Gravity Flame Reactor (IGFR). Variation in the PAH composition present in the samples is obtained by varying the flame temperature. PAH concentration of 16 PAHs is obtained in the PM samples using GCMS. This data is used to train and validate a linear model correlating EEM spectra of PM samples to the corresponding PAH concentrations of the samples obtained using GCMS. We test the model on diesel and woodsmoke samples and determine its accuracy.
Results & Conclusions	The model developed and tested using just IGFR samples has an overall error of 34% in the prediction of all 16 PAHs. The error is lower for PAHs present in relatively higher concentrations. This method can be used to quantify carcinogenicity and acute toxicity in air pollution samples which will improve the assessment of effects of air pollution on human health significantly.
Images	

Caption Figure 1:



Process of obtaining Excitation Emission Matrix (EEM) from combustion generated PM

Caption Figure 2:



Predicting PAH concentration using developed model

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Publication title	The impact of cloud processing on the ice nucleation abilities of soot particles at cirrus temperatures
Publication type	Poster
Introduction & Background	Soot particles influence the Earth's radiation budget by directly absorbing solar radiation but can also contribute to cloud formation by nucleating ice crys-tals or activating into cloud droplets, thus affecting climate through aerosol-cloud interactions. A quanti-tative understanding of the aerosol-cloud interac-tions of soot particles, especially their potential to form cirrus clouds, is a key factor to reduce uncer-tainties in the estimates of the net radiative forcing of soot particles (Bond et al. 2013). On a global av-erage, an aerosol particle is cycled three times through a cloud system before being deposited to Earth surface (Pruppacher and Jaenicke 1995). Giv-en the relatively long lifetime of soot particles of up to a week, this estimation might be a lower limit for carbonaceous aerosols. The ice nucleation ability of soot particles can be altered when involved in cloud processes. Thus, the cloud processed particles re-leased back to the atmosphere can have different cloud formation potentials with implications for the radiative properties of soot. In this study, we investi-gate the ice nucleation ability of cloud processed soot particles for different processing scenarios.
Methodology	The ice nucleation ability of propane flame soot, generated from a miniCAST burner, was investigated in the temperature range 233-218 K using the hori-zontal ice nucleation chamber (HINC, Lacher et al. 2017), a continuous flow diffusion chamber. By coupling two identical HINC chambers in series, we can simulate a cloud processing cycle in the first chamber and test the ice nucleation ability of the cloud processed aerosols in the second chamber. A temperature-controlled transition apparatus allows us to control the temperature along the complete trajectory of the particles. Transmission electron mi-croscopy (TEM) is used to inspect the morphological properties of unprocessed and processed soot aggre-gates. We complement our measurements by dy-namic vapor sorption (DVS) to quantify the soot hygroscopicity based on water sorption isotherms.
Results & Conclusions	We observe negligible heterogeneous freezing of the unprocessed propane soot particles in the first cloud formation cycle, with ice formation very close to homogeneous freezing conditions. After the first cloud cycle, the soot particles are more compact as evident from our TEM results. They are also more hygroscopic as our DVS results show. If the cloud processed soot aerosols are re-exposed to an ice nu-cleation cycle within the second HINC, their ice for-mation ability is significantly enhanced with relative humidity (with respect to ice) conditions required to trigger ice formation being up to 15% lower com-pared to the first cycle, depending on the processing scenario.

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Publication title	The influence of boiler type, Hg and As content in combusted coal on the content of these elements in chimney soot as a source of air pollution
Publication type	Poster
Introduction & Background	Apart from the main elements (C, H, O, N), coal contains a number of toxic elements including mercury and arsenic. Mercury is a highly toxic heavy metal and the human body does not demonstrate physiological demand for it. Hg and As are classified by the US Environmental Protection Agency (US EPA) as hazardous air pollutants. They are also elements with a very high bioaccumulation factor. Moreover, according to the data from the International Agency for Research on Cancer, As has a proven carcinogenic effect. One of the main users of hard coal, apart from the electricity and heat generation sector, is the communal and living sector. Individual consumers in Poland burn an average of 10 million Mg of hard coal annually, which is associated with a significant emission of these elements to the atmosphere estimated at the level of 1.1 Mg / year and 16.9 Mg / year, respectively for mercury and arsenic. The average content of Hg and As in Polish subbituminous coals ranges from 25 to 300 μg•kg-1 and 0 ÷ 40 mg•kg-1, respectively. International activities aimed at reducing of their emissions to the environment prompted to start research on the content of these elements in the burned fuel, their behavior in the combustion process and monitoring of their emissions. In the case of domestic boilers, one of the possibilities to reduce mercury and arsenic emission is the use of coals with a low content of these toxic elements and the use of chimney electrostatic precipitators that allow to remove a significant amount of fly ash and soot particles from the exhaust fumes and thus Hg and As adsorbed on their surface.
Methodology	Samples for testing were taken from domestic boilers of various classes, fired with hard coal. Determination of mercury and arsenic content in raw coals as well as in chimney soots derived from their burning were made using the DMA-80 analyzer and the Atomic Absorption Spectroscopy technique, respectively for determination of mercury and arsenic content.
Results & Conclusions	The aim of this work was to determine the influence of the boiler type and the content of mercury and arsenic in the combusted fuel on the content of these elements in the chimney soots, which emitted into the atmosphere constitute a serious source of air pollution forming smog in residential areas. The results will be presented during the conference.

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Publication title	White Spots on the Emission Reduction Roadmap
Publication type	Poster
Introduction & Background	Emission Legislation unfortunately was allways very selective and seldem respected the Swiss legal requirement that toxic emissions must be reduced to the extent possible in order to protect human beeings, anamals and nature. The stakeholders in the policy decision groups were mostly commercially motivated and not by ambient pollution periorities. The Diesel Scandal 2015 is the most famouns case but only one within many others .
Methodology	The method to select the right policies should not be a majority vote nor a Delphi oracle but straight forward engineering BAT considerations supported by cost/effect analysis.and this shuld not be limited to large exposure groups but also to small and sensitive subgourps although there might by no obvious return of investment.
Results & Conclusions	VERT network allways followed this principle and based on this has started research on: - petrol engine particle emission - PAH Trojan horse effect and required technical measures - New periodic technical inspection for all vehicles - efficient filters and De-Nox for marine emissions - implement secondary emission in legislation - reduce emission of handheld 2-stroke engines like chain saws - implement 4-way catalyts in pertrol cars - require upgrade be OEM VERT has recommended this for post Euro6 emission strategies via a hearing of the Euoropean court of auditors following the request of the European parliament.

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Publication title	PM ambient must be specified by EC like PM tailpipe by PN
Publication type	Poster
Introduction & Background	EURO 5/6 was a breakthrough because the EU adopted the PN criterion for emission control, originally introduced for offroad DPF retrofit in Switzerland and soon after applied this also for NRMM and petrol engines. Only by this it became possible to enforce the use of highly effeicient particle filters in all engines. The respective step for ambient particlulate pollution is still missing although it has been shown many times that PM is not correlating to EC and in some cases is even anticorrelating as scavenging observations have clearly shown, presented at ETH-NPC by Seippenbusch and Kasper..
Methodology	Analysing EC from PM samples is state of the art and has been used in occupational health since the Johanesburg-conventions. For many years the so called coulometric analysis has been used, now refined by new ISO-Standards and used by many European cities for a new EC inventory, like in Switzerland since years within the NABEL-network. [1]
Results & Conclusions	Using EC-information for workers exposure in 8 US-mines [2] where over 198 lung cancer death within a group of 12'315 workers had been found led to the conclusion of the EHO that Diesel exhasut gas needs to be classified carcinogenic class 1 in 2012. This conclusion was basically not correct because the toxic element according to this study was not a gas but the EC aerosol. A Durch group [3] further concluded that the EC concentration for lifelong exposure must stay below 0.1 migrogramm/m3 in order to reamain below the critical risk of 4 cancer cases per 100'000. With this evidence the legislation should include EC - or solid submicron numer concentration - in the set of ambient limit values.[4] [1] Hüglin EMAP: Swiss Nabel network [2] Silverman 2011; National Cancer Institute; the Miners Study [3] Gezondhetsaad 17-384 OCR Oct. 2017 [4] C.REche; X.Querol et al Atm.Chemisty 2011: New considerations for PM, Black Carbon and Particle comber

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Coauthors	
Publication title	Particle Surface to characterize biologic activity - but which one ?
Publication type	Poster
Introduction & Background	Particles are characterized by mass, size, surface, substance, morphology and number concentration and some research provides evidence that particle surface is more important to characterize biologic activity than total mass or size or number [1]. With aerosols of more or less sherical shape this seems rather obvious since the surface of a sphere is well defined and smaller particles have much higher specific surface so for given total mass the overall surface of an aerosol containing smaller particles is larger so the mass has less importance than surface. A similar geometric discussion shows that PN again has a different characteristic and experimental results by [1] provided evidence that biologic effects correlate much better with surface than mass of number or size
Methodology	With combustion soot particles the definitions are more difficult, since these particles are agglomerates of primary combustion particles, which are quite dense and are formed in a small size rang of 15-25 nm. Larger soot particles are just agglomerates containing more primary particle, The primary particle specific surface is in the range of 200 m2/g and agglomerates consisting of more or less primary particles must therefore all have the same specific surface ! Specific surface of soot particles is independent on particle size, a constant which only depends on the size of the primary particles. If it comes to surface definitions the soot particle provides different options, which are all very different:: - the equivalent sherical surface - the Fuchs-surface, which is the projected surface - the lung deposted surface area LDSA - a value which is closely linked to DC-response - the BET-surface, which is the biologically weddable surface - in fact the overall surface of all primary particles in the agglomerate.
Results & Conclusions	For biologic considerations the general agreement is that BET-surface is the decisive parameter. This is usually difficult to measure but in soot it is very simple to calculate from overall particle size and primary particle size. Particles of a given size range consist of the same number of spherical primary particles so they have the same BET surface. Furthermore: since particle size distributions of engines are lognormal and very similar, which means that the mean diameter is more or less the same in the range of 80 nm for Diesel (petrol 50 nm) the number of eqally sized particles is proportinal to the BET surface. And since a distribution is dominated by its mean value we can conclude that for soot particles number measurement gives the best proxi for BET surface.. Primary particle size is visible at the low end of the size distribution. With this the number count PN being proportinal to BET is the best parameter to charcterize biologic activity and having measured particle size as well (as we do with DC) we can calculate BET and mass.

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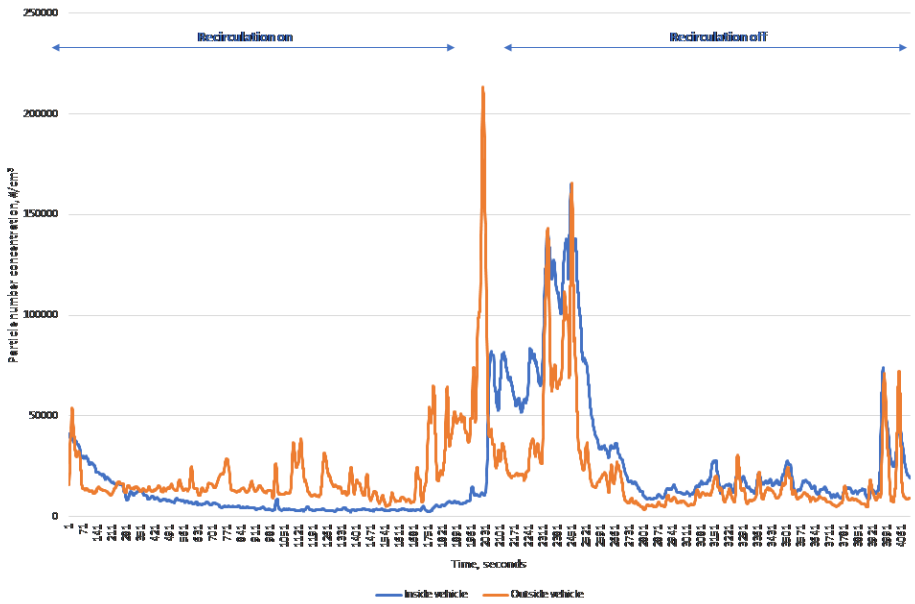
Publication title	Comparative ratings of vehicles for ultrafine particle exposure in the cabin
Publication type	Poster
Introduction & Background	While some research has been conducted on particle concentrations in the vehicle cabin, this study aimed to create a method for measuring particle infiltration rates in real on-road conditions in a way that allowed inter-vehicle comparison. A further objective was to test a large number of vehicles according to the method in order to create a performance rating scheme. With typical commuters spending 5-10% of their day in a car, and professional drivers longer, the potential health effects of particle exposure are potentially significant. A ratings scheme could bring about reductions in exposure by incentivising manufacturers to improve filtration, and to understand the most suitable settings for the heating and ventilation system while driving.
Methodology	Each vehicle was instrumented with a matching pair of condensing particle counters (CPCs), with a lower size cut-off of 15nm. The units were secured inside the cabin, and were equipped with low-loss sample lines. One unit sampled outside the vehicle, with the sample run through a side window and the window sealed. The second unit sampled inside the vehicle at head-height in the passenger's seat, to mimic driver exposure. Each vehicle was tested with a driver and no passenger over a repeated half-hour route on urban roads in Los Angeles, USA. Each vehicle was subjected to a static test with a canister of particulates deployed in the cabin to measure how quickly the concentration returned to background levels. The dynamic and static tests were run with recirculation on and off, and at different fans speeds.
Results & Conclusions	A method was successfully devised and executed, collecting results for around 70m vehicles. The repeatability of measurements was quantified and, in the light of uncertainty levels, a ratings classification was created. The ingress and clean-up rates differed significantly from vehicle to vehicle, reflecting the different types of filters installed and control strategies in the ventilation system. With recirculation on, rates of infiltration were significantly lower than with recirculation off. With recirculation off, in some cases the average interior concentrations exceeded exterior concentrations as particulates accumulated inside the cabin. Particle clean-up from the static test showed faster rates with recirculation on and with higher fan speeds.
Images	

Caption Figure 1:	 Transient particle concentration inside and outside of vehicle

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Coauthors	Sebastian Espitia-Cano; Andres F. Rosero
Publication title	Ultra-fine particles emission factors for the BRT fleet in Bogota: A Base-line for the evaluation of a fleet renewal project
Publication type	Poster
Introduction & Background	TransMilenio is a bus rapid transit system (BRT) that operates in the city of Bogota, Colombia. The current bus fleet is composed by two thousand and five diesel-powered buses, mostly operating Euro II, III and IV technology. The system transports nearly 1.2 million passengers daily. Previous research has shown extremely high concentrations of CO, Black Carbon (BC), Ultra-fine particles (UFP), and PM2.5 inside the BRT system stations and buses (Morales Betancourt et al., 2017). Due to the high in-cabin concentrations and the long travel times, it has been shown that the mean PM2.5 dose inhaled by commuters in a typical round trip in the system might be 1.2 times the dose a subject would inhale over 24h exposed to WHO guideline of 25 µg/m3 (Morales et al.,2019). Although the concentration experienced by the users of the system have been characterized in a few studies, the emission factors (EF) for the BRT fleet have not received the same degree of attention. Starting in July 2019, a new bus fleet will replace nearly 1400 18-year-old diesel-powered buses that are part of the current BRT system. The new fleet will include natural-gas and EURO-V DPF-equipped diesel-powered buses. This new fleet is expected to significantly reduce emission rates of Black Carbon and PM2.5, but the behavior of ultra-fine particles (UFP) emissions is unknown. Therefore, the main goal of this work is to characterize, through the carbon-balance method (Singer and Harley, 1996), the evolution of UFP fuel-based emission rates during the transition period.
Methodology	We utilized the carbon balance method together with an automated video analysis software to measure emission factors for individually identified BRT buses. Instrumentation was deployed at seven roadside monitoring sites next to the exclusive BRT lanes. The sites were selected at locations where it is expected to get the largest differences attributable to the influence of the new vehicle fleet. Carbon Dioxide (LI-CO3 820), BC (Aethalometer AE33), and aerosol particle mass and number of UFP (Dekati DMM-230 and Diffusion size classifier, DiSCmini) were measured at 1Hz. Typical monitoring duration was three hours per day. The data was postprocessed, and the video-analysis software was used to individually identify the BRT buses associated with the micro-plumes detected by the measuring devices.
Results & Conclusions	Thirty nine emission factors of BC and UFP have been obtained. Average EF for BC was 0.4 g/kg-fuel, while average UFP emission factor was 9.5×10^14 #/kg-fuel, with a maximum of 5.6×10^15 #/kg-fuel. Regarding the technology type, the mean UFP emission factor obtained for Euro II, III, IV and V were 9.49×10^14, 8.83×10^14, 1.46×10^15 and 1.82×10^15 UFP #/kg-fuel respectively. These preliminary results which show relatively low UFP emission factors and the large BC emission factors, suggest that the old portion of the fleet is emitting relatively large particles composed of large clusters of elemental carbon and condensed species. The second part of this study will be carried out after the BRT fleet is renewed to establish the net change in the emission factors after the implementation of the new fleet with natural-gas and EURO-V DPF-equipped buses.

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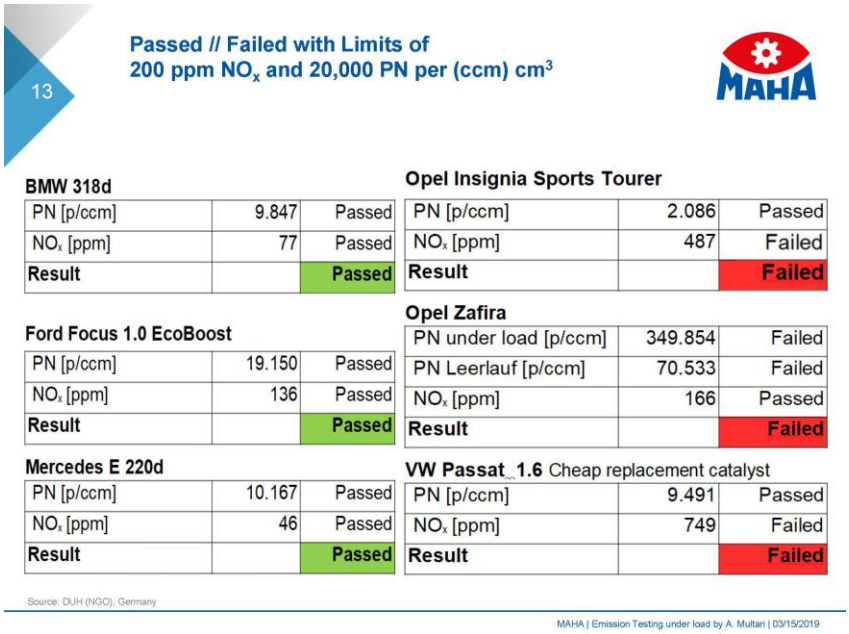
Publication title	Emission Testing under load for Pollutants e.g. NOx and PN
Publication type	Poster
Introduction & Background	Todays need of doing a reliable emission testing based on tail pipe testing is after the VW Diesel gate no more a question. It is obvious to measure at the end of the combustion and after treatment process the exhaust emissions. The need of checking Particulate Numbers (PN) and Nitrogen Dioxides (NOx) is a demand from the environmental and health protection bodies. But also PTI needs to differentiate between the working after treatment system and the non-working. This presentation gives a fast, robust and reliable solution of checking PN and NOx under load. A new MAHA system combines a brake tester for doing also emission testing under load. Also proposal for ambitious limit values are included.
Methodology	- As the measurements for NOX only makes sense under load conditions a new developed combined brake and load roller test stand was used for a new developed PTI test. The measurements should be made under load with warm engine. The vehicles should be accelerated from idle under 1,500 Newton meters of load within five seconds to 20 km / h, ten seconds driven at 20 km / h and then braked back to idle. - The test-roadworthy roller brake tester is designed for cars and vans up to 3500 kg axle load and has a single-wheel circuit for differentiated, wheel-wise considerations. - For exhaust gas measurement existing PTI measuring devices can be used to determining the concentrations of nitrogen oxides. For the number of particles PN prototype measurement devices can be used. - To test the proposed procedure Gasoline and diesel cars with different emissions standards were examined. The measurements are made under load with a warm engine. To determine the measured values, the vehicles were accelerated from idle under 1,500 Newton meters of load within five seconds to 20 km / h, ten seconds driven at 20 km / h and then braked back to idle.
Results & Conclusions	1. A PN limit value of 20,000 per cubic centimeter is proposed for checking the functionality of particulate filters. If the particle filter is working, the test values are well below this test value. 2. For the nitrogen oxide concentration, an average NOx concentration of 200 ppm (parts per million) for Euro 6 vehicles is proposed on the basis of a large number of RDE measurements with PEMS measuring instruments. 3. Based on these suggestions, some vehicles were assessed.
Images	

Caption Figure 1:



Passed // Failed with Limits of
200 ppm NOx and 20,000 PN per (ccm) cm3

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Publication title	Non-volatile particle number emissions from light- and heavy-duty vehicles and marine engines
Publication type	Poster
Introduction & Background	Exhaust gas particle emissions are well known of being harmful to human health and since early 1990's the particle mass (PM) emission have been limited in Europe by legislation. In addition PM limits the particle number (PN) emission legislation was introduced on 2011 for light-duty vehicles (Euro 5b) and 2013 for heavy-duty engines (Euro VI). In marine sector, the inland waterway vessels will be put under the PN regulation on 2020 regarding the highest engine power class (Stage V). PN measurement method for legislative purpose was developed by so called PMP-working group under the mandate from UNECE/GRPE. Method is based on hot primary dilution and evaporation of volatile compounds with evaporation chamber. Further on the sample gas is diluted on second stage before it enters to particle counter. In the legislation the D50% cut point for particle counter is set to 23 nm. In this study PN emissions from different sources, measured with legislative measurement system, will be presented and compared.
Methodology	Measurements were performed on light- and heavy-duty chassis dynamometers and with marine engines on laboratory as well as on-board of ships. Measurements with vehicles were performed using various driving cycles and fuels. With light-duty vehicles measurements were performed with gasoline, FFV/E85, natural gas and diesel vehicles representing Euro 6 emission classes. The measured heavy-duty vehicles were Euro VI emission level busses using diesel and natural gas. The marine engines were measured with marine gas oil (MGO), marine diesel oil (MDO), heavy fuel oil (HFO) and natural gas. The measurement set-up on chassis dynamometer measurements included CVS-tunnel, PN sampling unit (Dekati DEED) and particle counter (Airmodus A23 CPC). In marine engine measurements the CVS-tunnel was replaced by additional dilution unit and sample was taken from raw exhaust gas.
Results & Conclusions	Results give an overview of non-volatile PN emissions from different engine and vehicle applications using various type of fuels. With light duty-vehicles the lowest PN emissions were measured with diesel vehicle using diesel particulate filter (DPF) followed by natural gas and gasoline vehicles. With heavy-duty vehicles the PM emissions with diesel bus having DPF were lower compared to natural gas bus. Marine engines without DPF had the highest PN emissions, however the PN emissions with natural gas were comparable to natural gas vehicles.

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Publication title	Solid Particle Number Emissions of Gasoline Direct Injection Vehicles from CVS Versus Raw Exhaust Sampling
Publication type	Poster
Introduction & Background	The Solid Particle Number (SPN) emissions of Gasoline Direct Injection (G-DI) light duly vehicles are regulated in Europe since 2014. The tests are conducted by sampling diluted exhaust from a Constant Volume Sampler (CVS) system and its particulate matter and gaseous emissions are measured. Recently on-board measurements with a Portable Emission Measurement System (PEMS) have complemented the light duty vehicle regulation where the SPN measurements are conducted by sampling the exhaust from the vehicles' tailpipe. For SPN with the PEMS a Not-To-Exceed (NTE) emission limit with a Conformity Factor (CF) of 1.5 has been introduced to take into account the measurement uncertainly derived by such a method.
Methodology	Differences in the SPN emissions measured at the CVS and at the vehicles' tailpipe are evaluated under laboratory testing conditions. The tests were conducted at three different vehicle benches equipped with CVS tunnels. Two particle counters, which are compliant with UN-ECE R83, were deployed at each vehicle bench in order to measure SPN concentration of vehicle exhaust simultaneously over a test. The first particle counter sampled the diluted exhaust from the CVS tunnel, which is considered as a reference method, while the second particle counter sampled the undiluted one from the vehicle's tailpipe. A pitot-type exhaust mass flow meter was used to measure the vehicle's exhaust flow rate and was applied to the tailpipe measurement. Over 20 G-DI vehicles with or without a Gasoline Particulate Filter (GPF) were tested under the Worldwide harmonized Light vehicles Test Procedure (WLTP) and under a Real Driving Emission (RDE) cycle.
Results & Conclusions	The SPN differences between tailpipe and CVS tunnel were found to be up to 30%. This result is attributed by particle losses and particle internal processes such as agglomeration, which occur in the exhaust transfer tube from the tailpipe to the CVS tunnel. Factors influencing the measurement uncertainty are presented and their contribution to the current CF for the SPN emission is discussed.

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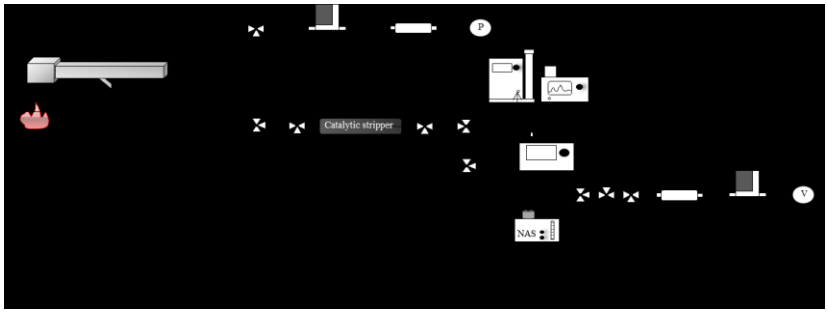
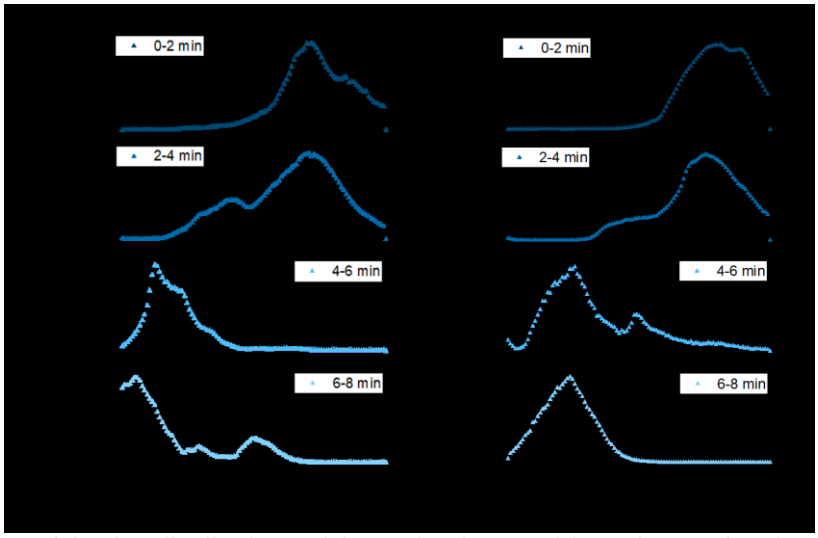
Coauthors	Tobias Hammer; Ari Setyan; Jing Wang
Publication title	Characterization of aerosol released from the combustion of nanoparticle-containing materials
Publication type	Poster
Introduction & Background	Incorporation of nanoparticles into the products has been extensively studied to improve the materials' properties such as mechanical strength, electrical conductivity, thermal properties and fire retardancy. Despite their advantages, there have been a number of studies on the po-tential risks of nanoparticles. During the life cycle of the products, nanoparticles might be released from the matrix, which could be harmful to the environment and human health [1]. One of the release scenarios is the combustion, which can occur either by an accidental fire or a waste treatment at the end-of-life of the products. The combustion process might also transform the released nanoparticles that could be more toxic than the original ones [2], [3]. It is important to understand which forms of nanoparticles were released after the combus-tion process so that the potential risks can be estimated. Although some studies have focused on characterization of the emissions from the combustion of nanoparticle-containing com-posites [4], [5], the results are still scarce and only cover limited types of nanoparticles. Therefore, this study investigated the characterization of aerosol emissions from the com-bustion of different nanoparticle-containing composites. Nanofillers used in this study were graphene nanoplatelet (GNP), SiO2, pigments, Ag nanowires and quantum dots.
Methodology	A large set of instruments was employed to characterize the size distributions, morphology, and elemental composition of the particles released from the combustion as shown in Figure 1. The FTT cone colorimeter was employed for testing the flame retardancy properties of the composites. During the combustion, the emissions were sampled directly above the flame. The emissions were diluted and cooled with the filtered air. A catalytic stripper could be ap-plied to remove volatile organic compounds. The particle size distributions were measured on-line using scanning mobility particle sizer (SMPS) and aerodynamic particle sizer (APS). The emissions were collected using a nanometer aerosol sampler for further SEM analysis. Chemical compositions of the emissions as both particulate and volatile forms were ana-lyzed by SEM/EDX and GC/MS.
Results & Conclusions	The preliminary results were obtained from one of the studied composites namely epoxy/graphene nanoplatelet. The burning time of the epoxy composites lasted for approxi-mately 8 minutes. The results with or without using catalytic stripper showed similar trends. The total particle concentrations were higher at the beginning of the combustion and gradu-ally decreased until the flame was out. The particle size distributions between 0 and 4 minutes after the flame started showed that the modal size of the emitted aerosol particles from neat epoxy were around 200 nm. Between 4 and 8 minutes, the emitted particles be-came smaller with the modal size approximately 20 nm. The emitted particles from the combustion of epoxy/1wt% GNP during the first 4 minutes of burning showed the similar modal size as compared to neat epoxy, whereas the emitted particles during 4 to 8 minutes were around 30 nm. The main compounds of the emissions analyzed by GC/MS were aro-matic compounds and poly aromatic hydrocarbons. More detailed characterization of the emitted particles needs to be performed.

Images	
Caption Figure 1:	 Schematic experimental set up for characterization of aerosol released from the cone combustion of the nanoparticle-embedded composites
Caption Figure 2:	 Particle size distributions of the emitted aerosol from the combustion without using a catalytic stripper of a) neat epoxy and b) epoxy/1 wt% GNP

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Publication title	Gasoline exhaust filtration as a valid method of obtaining particulate matter for further analysis.
Publication type	Poster
Introduction & Background	Since 1950s emission from the fossil fuelled cars have been considered as a harmful. The car exhaust gasses are part of the low emission therefore they are especially dangerous for human health and environment. In the past many methods were used to measure level of toxicity and harmfulness of exhaust components. In the last year in Europe a new measuring method - Worldwide light duty harmonized test cycle - was considered as a standard. The WLTC that is part of the Euro 6 emission standard allows to achieve the true values of fuel consumption and emissions. The test is carried on the chassis dynamometer in the air conditioned chamber.
Methodology	Part of the exhaust gasses are redirected through the filtration system in which the particulate matter (PM) is collected on the 47 mm via. membrane filter. The PM is composed of the unburnt gasoline, engine oil and particles from engine wear. After the test filters can be analysed with scanning electron microscope (SEM) that allows to enumerate the concentration of the particles and measure the dimensions of the single particle collected on the surface.
Results & Conclusions	Further analysis of the particulate matter might be carried out by the gas chromatography with mass spectrometry that will allow to analyse polycyclic aromatic hydrocarbons (PAHs) and their derivatives in the form of nitro-PAHs and oxy-PAHs. Additionally ion chromatography will allow to study the cations and anions contained in the particulate matter. Studies may allow to better understand their origin and to improve and develop methods to decrease their content in the car exhaust fumes. Acknowledgment: The work has been completed as a part of the research subvention at the AGH UST in Krakow (no. 16.16.210.476), with substantive and financial support of Institute for Sustainable Energy and using infrastructure of the Centre of Energy, AGH UST in Krakow. Poster presentation was was financialy supported by the PROM International scholarship exchange of PhD candidates and academic staff implemented by Polish National Agency For Academic Exchange (PPI/PRO/2018/1/00026/U/001)

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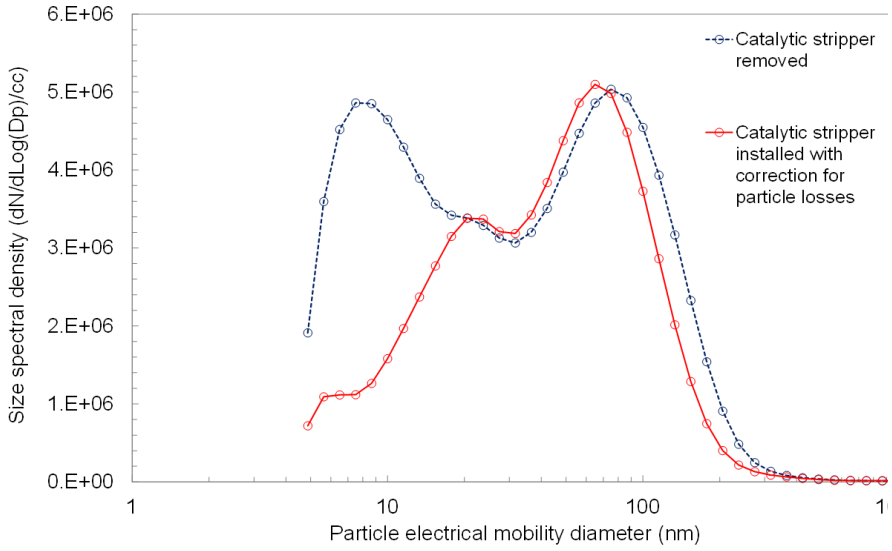
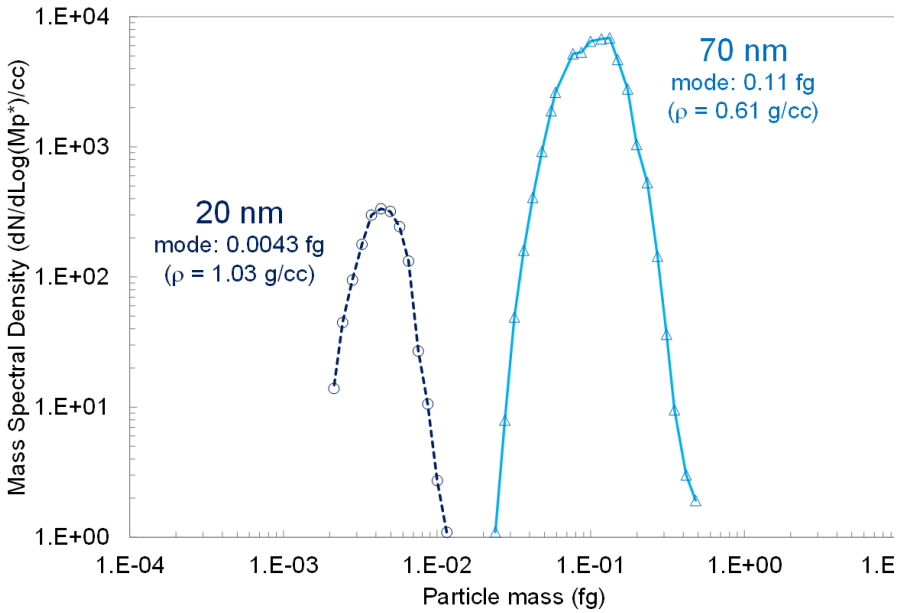
Publication title	Multi-Instrument Characterisation of Particulate Emissions from a Gasoline Direction Injection Engine: Investigation of Size, Volatility and Density
Publication type	Poster
Introduction & Background	Gasoline direct injection (GDI) engines offer higher specific power output and fuel economy compared with port injection gasoline engines, but generally emit more particles (both by mass and number) and are therefore a potential source of ambient particle pollution in urban areas. The introduction of a particle number limit for gasoline vehicles in the Euro 6 emissions standards is expected to lead to widespread adoption of the gasoline particle filter (GPF). Particle emissions from combustion engines are usually a combination of solid particles and condensed semi-volatile material. The solid particles include soot aggregates and ash; the latter can be a source of catalyst poisoning in coated GPFs. In this study, the nature of particulate emissions from a GDI engine was investigated using a range of instruments to determine the size distribution, the effect of removing the semi-volatile fraction and to measure the density.
Methodology	A 2.0 litre turbocharged GDI engine generating a maximum power of 180 kW at 5500 rpm was mounted in transient engine dynamometer cell equipped with a constant volume sampling (CVS) tunnel. The engine was fuelled with Euro 6 Gasoline (E10). A Differential Mobility Spectrometer (DMS) was used to sample raw exhaust upstream of the turbocharger, with and without a catalytic stripper in the sample line, and with the engine undergoing a Worldwide harmonised Light vehicle Test Cycle (WLTC). Tests were repeated under steady-state conditions with the engine speed at 2700 rpm. DMS measurements were also made sampling from the CVS, which were repeated with a Scanning Mobility Particle Sizer (SMPS). To investigate the nature of the particulate matter in more detail, DMA-classified particles taken from the peak of each mode were directed through a Volatile Particle Remover (VPR) with a Condensation Particle Counter (CPC). The number mass distribution of the classified particles was then scanned with a Centrifugal Particle Mass Analyser (CPMA).
Results & Conclusions	A 9 nm mode that was present during both the low and high speed sections of the WLTC was largely removed by a catalytic stripper. Figure 1 shows the average number size distributions measured by the DMS during the high speed section; while semi-volatile 9 nm particles were removed, an additional mode at 20 nm persisted through the catalytic stripper (along with the expected soot accumulation mode at 70 nm). This was also observed when the engine was operating under steady-state conditions, and again when sampling from the CVS with the SMPS. Aerosol from the CVS was classified in the DMA and it was found that 20 nm particles were not removed by the VPR (therefore they are defined as solid). The masses of particles selected from the 20 nm and 70 nm modes with the DMA were scanned with the CPMA; the results shown in Figure 2 are consistent with an effective density relationship for fractal-like soot aggregates and are not indicative of ash. Possible explanations for the shapes of the solid particle size spectra are explored, with reference to examples in the literature where GDI soot size distributions are not lognormal, but asymmetric on the log scale with higher particle concentrations for smaller particles.

Images	
Caption Figure 1:	 DMS spectra obtained upstream of the turbocharger during the high speed section of the WLTC, with and without a catalytic stripper in the sample line
Caption Figure 2:	 CPMA scans of DMA-classified particles taken from the peaks of the modes from the solid particle spectra

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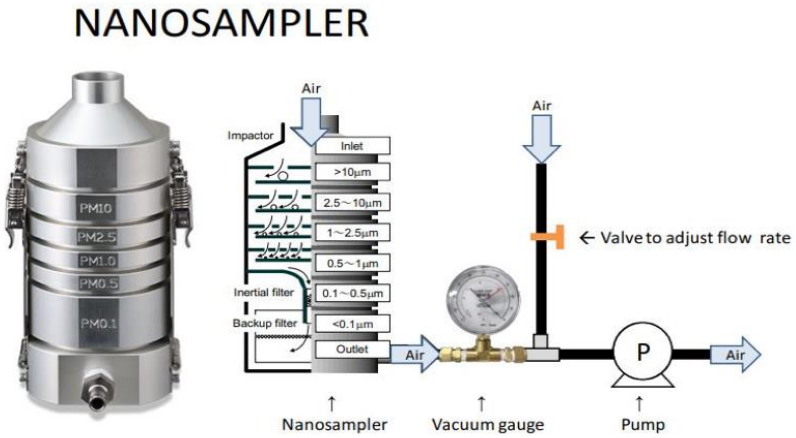
Coauthors	Muanfun Inerb; Panwadee Suwattiga; Thaneeya Chetiyanukornkul; Perapong Tekasakul; Surajit Tekasakul; Mitsuhiko Hata; Masami Furuuchi
Publication title	Ambient Nano-aerosol and Carbon Components in Thailand
Publication type	Poster
Introduction & Background	Thailand and neighboring countries in Asia have agriculture-based economies and generate a large number of agricultural residues, which are burnt in the field and also burnt in agro-industry. Furthermore, emissions from motor vehicle and forest fires make an extensive contribution to the volume of carbonaceous aerosols in Thailand. Nevertheless, only a few publications have reported and reviewed the behavior of carbon component in aerosols in Thailand. There has been a lack of studies of atmospheric nanoparticles (PM0.1) in Thailand, especially in urban and suburban areas. Moreover, the PM0.1 ambient particle related to carbon components has not so far been studied in Thailand and neighboring countries.
Methodology	The sampling sites at 3 cities in Thailand including Chiang Mai (North), Bangkok (Central) and Songkhla (South). The particulate matter (PM) was collected by cascade air samplers for nanoparticles. The Nano-sampler can be used to sample a greater amount of nanoparticles at ambient pressure. The used sampler consisted of four impactors stages (>10, 2.5-10, 1-2.5, 0.5-1 μm), an inertial filter stage (0.1-0.5 μm) and a backup filter (
Results & Conclusions	The results showed that ambient nano-aerosol in Chiang Mai, Bangkok and Songkhla around 24%, 14%, and 10%, respectively. OC and EC from nanoparticle are also measured to confirm the emission source. In Chiang Mai, the northern part of Thailand, forest fires occurring upwind of the site were found to be the largest contributor while the carbon behavior at the site in Bangkok was better described by the motor vehicle in Bangkok and open biomass burning from the surrounding provinces in the central Thailand region. On the other hand, southern Thailand the road transportation was the main source of nano-aerosol, except for some period effects from transboundary migration over countries.
Images	
Caption Figure 1:	 Figure 1. Nano-sampler for Atmospheric Nanoparticle Collection

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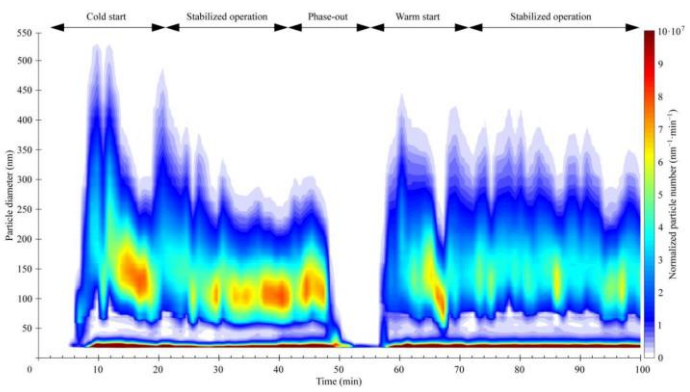
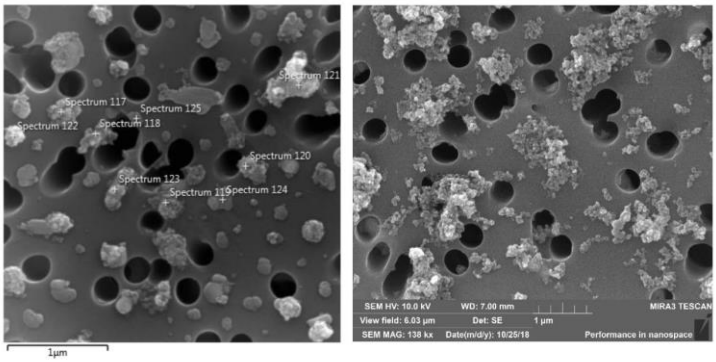
Publication title	Experimental Investigation of Concentration and Size Distribution of Fine Combustion Particles Emitted by Small Biomass Boiler under Various Operation Conditions
Publication type	Poster
Introduction & Background	This poster deals with the experimental identification of concentration and size distribution of fine combustion particles emitted by domestic biomass combusting boiler. The poster presents a testing procedure of real biomass boiler with detail monitoring of the concentration and size distribution of emitted particles smaller than 1 micrometre (PM1). The flue gas leaving the boiler enters a Scanning Mobility Particle Sizer (SMPS) where the particle size fractions are separated. A number of particles is identified by the condensation particle counter (CPC). The combustion of solid fuels in boilers is associated with significant production of fine particles entrained in flue gas. The concentration of fine particles in flue gas and their size distribution are influenced by many parameters, i.e., fuel composition, fuel humidity, oxygen excess, combustion temperature, and residence time of flue gas in the combustion chamber, etc. Despite the considerable efforts of a number of research teams, the process of particle creation (nucleation) and particle growth in the flue gas stream is not yet satisfactorily explained.
Methodology	A 20kW automatic pellet boiler was used for the experimental measurements. Two different types of fuel pellets were tested in this study, specifically spruce-pellets and agro-pellets. The agro-pellets were formed from waste agricultural biomass (rape straw). The aim of the study is to determine experimentally the concentration and size distribution of fine particles in flue gas leaving a pellet boiler. For this purpose, a sequence of operating conditions was designed including the following in a chronological order: 1) cold start of the boiler, 2) a steady operation of the boiler with rated burner parameters, 3) combustion attenuation, 4) warm start of the boiler, 5) a steady operation with rated burner parameters, 6) boiler extinction. The same operating condition sequence was used for spruce-pellets and subsequently also for agro-pellets. The entire testing sequence takes 120 minutes. After it was carried out it was necessary to let the boiler cool down so that the temperature in the combustion chamber would fall under 40 °C. Subsequently, another operating sequence was carried out starting with a cold start.
Results & Conclusions	Based on the experimental measurements, we can formulate the following operational recommendations. To reduce the production of fine particles during biomass combustion it is crucial that the surface temperature of the combustion chamber walls is sufficiently high. In a heated combustion chamber a smaller number of particles are formed than in a chamber with cold walls. Also, during the ignition of fuel in a heated chamber there is significantly lower production of fine particles compared to a cold start. This leads to boiler power modulation being preferred to cyclic boiler switching-off and ignition. During combustion in a well heated combustion chamber only a slight difference in the production of fine particles was observed using various fuel pellets.
Images	

Caption Figure 1:	 The development of concentration and size distribution of FP in flue gas; spruce
Caption Figure 2:	 Combustion particles cought in the combustion product of a pellet boiler

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Coauthors	Patrick Huth; Hannah von Blumröder; Axel Friedrich
Publication title	Indoor air pollution with ultrafine particles from stoves
Publication type	Poster
Introduction & Background	Residential heating with wood (and coal) in small private stoves is a well-known source of outdoor air pollution. However, only a few studies have investigated indoor air pollution with ultrafine particles from stoves. Even though, stoves are placed inside houses and thereby can emit particles directly to the indoor air. Thereby stoves could cause serious indoor air pollution when people are at home in the winter season where ventilation is typically limited.
Methodology	This study investigates indoor air pollution with ultrafine particles emitted directly from typical wood stoves placed in living rooms inside Danish houses. Both pollution from old wood stoves and new stoves with an eco-label (Nordic Swan) were investigated in 20 single-family houses. Measurements were carried out from about 15 minutes before using the stoves and then for 2 to 3 hours during normal use of the stoves by the house owners. Measurements were performed in realistic inhalation distance from the stoves (2 to 3 meters) with P-Traks.
Results & Conclusions	In 20 percent (4 houses), no significant increase of indoor air pollution with ultrafine particles when using the stoves was observed. In the other 80 percent (16 houses), a significant increase of indoor air pollution was measured: In six houses, an increase in pollution levels up to a factor 10 was observed when using the stoves. In half of the houses, pollution increased more than a factor 10 when using the stoves. In the worst 20 percent pollution increased more than 50 times reaching much higher levels than the most polluted streets in the rush hour. In two houses, we measured in other rooms as well and found that the high air pollution had spread to all rooms with open doors or stairways directly connected to the living rooms with the stoves. The indoor air pollution with ultrafine particles from stoves is believed to be caused by direct leaking from stoves, smoke coming out when refueling with wood and/or particles from burned dust on outer stove surfaces. In some cases, it was clearly one cause dominating the observed particle emission whereas it was probably a combination in other cases. A well-functioning draught in the chimney is believed to explain why some stoves could be used without or almost without increasing indoor air pollution. No connections between the age of the stoves or eco-label stoves and indoor particle pollution levels were observed. Similar measurements were carried out by the authors in Germany, Czech Republic, Slovakia and Hungary showing comparable results and underlining that air pollution from small private stoves can be an important pollution source to indoor air pollution i.e. pollution in our homes where we inhale most of our air over a lifetime and clean air thereby is crucial.

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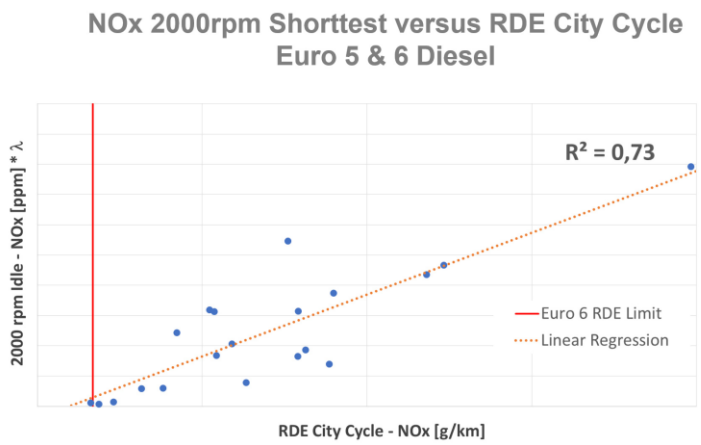
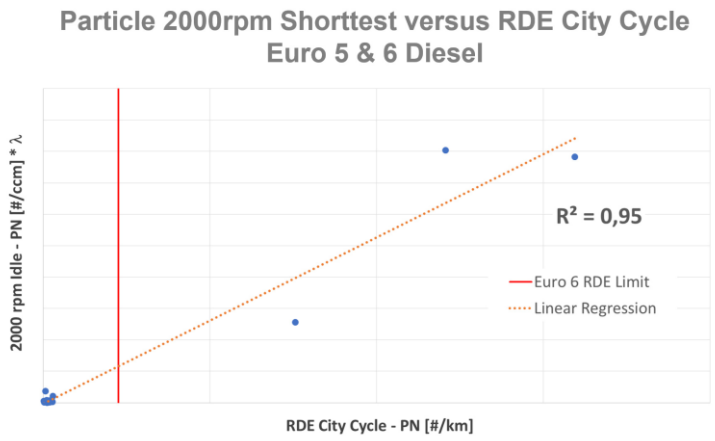
Coauthors	Andreas Gruber; Andreas Eidmann, Christian Spitzwieser
Publication title	Validation of a Universal Short-Test Procedure für PN and NOx by RDE Measurements
Publication type	Poster
Introduction & Background	At least since the diesel gate scandal, the public has become aware of the possibilities of digital control units, and so it is not surprising that one does not trust the on-board diagnostic functions too much. The inspection system needs reliable methods to detect, on the one hand exceeding particulate and gaseous emissions of motor vehicles during periodic technical inspections (PTI) and, on the other hand, to detect the malfunction of the exhaust aftertreatment system. The authors of this presentation have taken up this topic and compared the universal short test procedure for internal combustion engines with full RDE measurements. The results of PN and NOx of this extensive investigations of more than thirty Euro 5 and 6 vehicles will be presented.
Methodology	The procedure is similar to the PTI exhaust gas test, which has already been carried out in Europe for several decades on internal combustion engines with gasoline engines and three-way catalytic converter. The engine is measured for at operating temperature and 2000 rpm constant high idle speed. In addition to the previously measured concentrations of CO and HC particle number and NOx are determined. The values are related to the equivalent air-fuel ratio Lambda to prevent fluctuating results of non-stochiometric engines. The measuring system used is a further development of the established RDE-device OBM, which was adapted for stationary exhaust gas analysis.
Results & Conclusions	The results showed for PN as well as NOx very satisfying correlations between the new short test procedure at high idle and RDE city cycle. This instrument significantly upgrades the periodic inspection of motor vehicles on the road, as it reflects a real emission behavior at the tailpipe of the exhaust system and does not make use of car specific engine control data.
Images	
Caption Figure 1:	 2000rpm Shorttest versus RDE City Cycle

Caption Figure 2:	 Particle Number 2000rpm Shorttest versus RDE City Cycle

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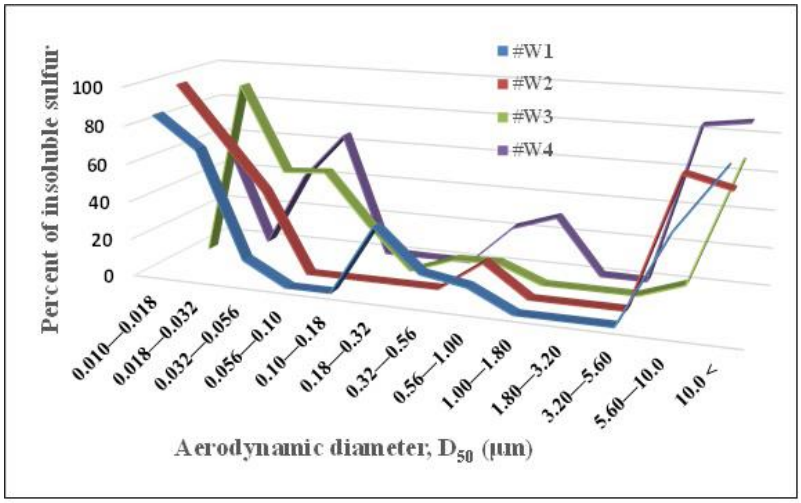
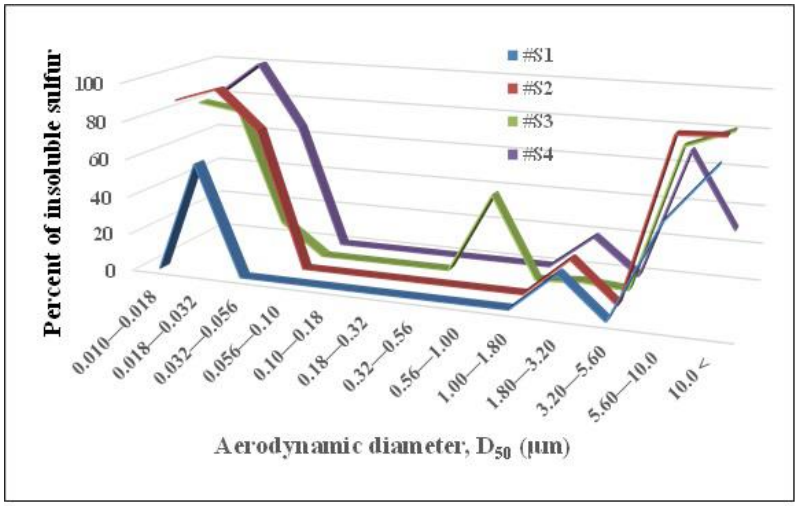
Publication title	Characteristics of chemical composition for ultrafine particle collected at Narita International Airport
Publication type	Poster
Introduction & Background	Jet engine aircraft are a significant source of atmospheric ultrafine particle (particles with aerodynamic diameter < 100 nm) and exist ubiquitously from ground level to the upper troposphere. Although countermeasures against exhaust particles from jet engine is underway, the number of flight departures and arrivals of aircraft is increasing year by year and the runway is also expanding, so the influence on the atmospheric environment to near the airport is apprehensive. Therefore, it is important to know the chemical composition of the ultrafine particle. We have therefore collected particulate samples from an area near a runway at the Narita International Airport, Japan, during winter period (February) and summer period (July—August) in 2018, and underwent chemical analysis.
Methodology	Two NanoMoudi II impactors were used to collect size-resolved particles (particles size range: 10—0.01 μm) in the ambient air. To distinguish the effect of aircraft emissions, the samples were collected during the daytime (during aircrafts operation hours; 7:00–22:00) and nighttime (during non-operation hours; 0:00–6:00). We obtained three daytime and one nighttime samples in the winter period, and two daytime and two nighttime samples in the summer period. For the analysis of the ionic and elemental composition, the size-resolved particles collected on a polycarbonate (PC) filter was used, and the size-resolved particles collected on a gold (Au) foil was used for analysis of elemental/organic carbon (EC/OC). Ionic species in the PC-filter samples were determined using ion chromatography (Metrohm IC 850). The Elemental composition analyses of the PC-filter samples were carried out using PIXE at the Nishina Memorial Cyclotron Center, Japan Radioisotope Association. The EC, OC and total carbon on the Au-foil samples were determined by using a thermal/optical carbon analyzer (DRI Model 2001 Carbon Analyzer).
Results & Conclusions	For the chemical components of ultrafine particle samples, the proportion of OC to the mass of PM is higher than the total values of ion species and element composition, and samples of OC values occupying more than 10% of PM mass were also observed. The ion species determined from the ultrafine particle samples were Cl−, NO3−, SO42−, (COO)22−, Na+, NH4+, K+, Mg2+ and Ca2+, and the main ions were NO3− and SO42−. Regarding the elements, 24 elements (Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Ga, Se, Br, Rb, Sr, Zr, Hg and Pb) were identified. The major elemental components were Mg, Al, Si and S. Sulfur compounds originating from jet fuels can be the major components of aircraft exhaust non-size-resolved particles. Therefore, to capture the behavior of insoluble sulfur and water- soluble sulfur (sulfate: SO42−) of size-resolved particles is important for evaluating the effect of aircraft exhaust particles. Looking at the ratio of insoluble sulfur and soluble sulfur for each particle size, insoluble sulfur accounts for about 50% in ultrafine particle. (Figure 1 and Figure 2) The result indicates the importance of sulfur not only fuel-derived sulfate. This work was supported by the Environment Research and Technology Development Fund (5-1709) of the Ministry of the Environment, Japan.
Images	

Caption Figure 1:	 Figure 1 Percentage of insoluble sulfur to elemental sulfur (PIXE analysis value) in size-resolved particles collected during the winter period. #W1: daytime sample (February 9—13); #W2: daytime sample (February 13—17); #W3: daytime sample (February 19—20); #W4: nighttime (February 22—26)
Caption Figure 2:	 Figure 2 Percentage of insoluble sulfur to elemental sulfur (PIXE analysis value) in size-resolved particles collected during the summer period. #S1: daytime sample (July 27—31); #S2: nighttime sample (August 1—6); #S3: daytime sample (August 6—10); #S4: nighttime (August 11—15)

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Publication title	Accuracy of particle size distribution and number concentration measured by the Engine Exhaust Particle Sizer (EEPS) spectrometer for particles in the size range from 6 nm to 300 nm
Publication type	Poster
Introduction & Background	In our recent field studies of measurement of nanoparticles emitted from aircrafts at an airport (Fushimi, A. et al., 2019), we used a TSI Engine Exhaust Particle Sizer (EEPS) spectrometer model 3090 for measurement of particle size distribution and number concentration in the size range from 5.6 nm to 560 nm. To evaluate the accuracy of the measurement data taken with the EEPS, we carried out laboratory tests on it. Performance evaluation methods for mobility-based instruments, however, have not been established, especially for particle number concentration. For conventional mobility-based spectrometers that consist of separable components, such as the charger, classifier (i.e., differential mobility analyzer, DMA), and detector, the performance can be evaluated to some extent by individually inspecting and/or calibrating the components. On the other hand, fast-response instruments, such as the EEPS, are packaged so that the integrated components are not separable for individual testing. For those instruments, techniques to evaluate the overall performance of a complete system as a whole are needed by treating each instrument as a “black box”.
Methodology	We evaluated the performance of the TSI EEPS used in the field studies in an airport with respect to the accuracy of the total number concentration of monodisperse particles. In this evaluation, the total number concentration of monodisperse particles of the same aerosol was measured in parallel with the test EEPS, a reference CPC, and a reference scanning mobility particle sizer (SMPS) spectrometer. The total number concentration of quasi-monodisperses or polydispersed aerosol particles that was obtained by integrating the size distribution measured by the test EEPS was compared with the number concentration measured by the reference CPC and SMPS. Monodispersed particles were generated by passing particles from an aerosol generator (e.g., electrospray or evaporation/condensation generator) through a neutralizer and subsequently classifying them with a DMA. Then, after mixed well with a particle-free dilution air, particles were delivered to the test EEPS, the reference CPC, and the reference SMPS simultaneously. By having the reference CPC being calibrated with traceability to a national or international standard (e.g., AIST's primary standard), the test EEPS calibrated by this method with monodispersed particles attained metrological traceability to the standards with respect to particle number concentration. In addition, the particle size distribution measured by the EEPS was compared with that by the reference SMPS. The tests were performed in the size range from 6 nm to 300 nm.
Results & Conclusions	It was found that the EEPS underestimated the number concentration for particles smaller than 30 nm, and the underestimation was more significant as the particle size got even smaller. Details of the test results will be given in the poster. Reference: Fushimi, A., Saitoh, K., Fujitani, Y., and Takegawa, N.: Identification of jet lubrication oil as major component of aircraft exhaust nanoparticles, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-1351, 2019.

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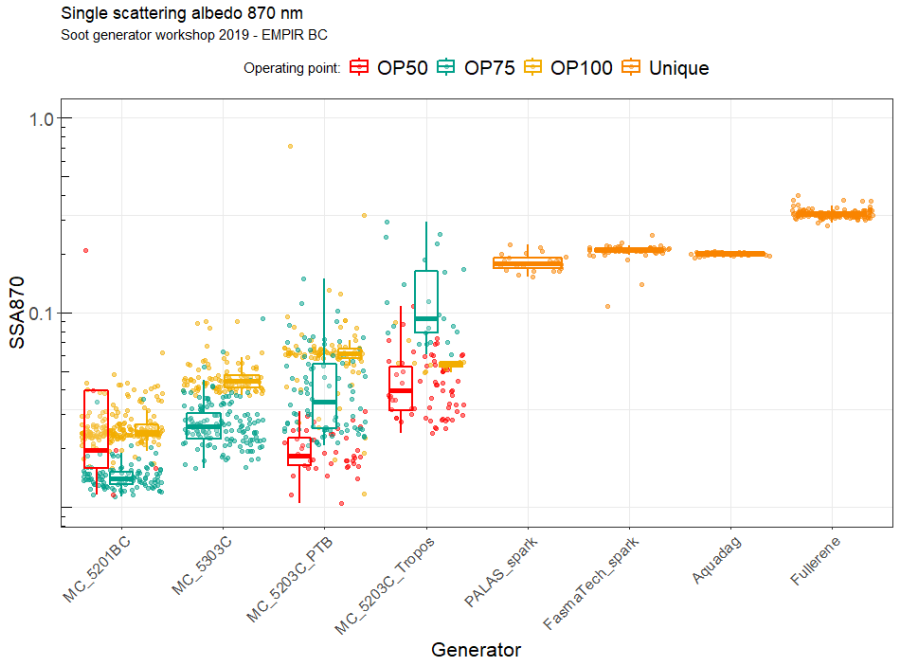
Publication title	Comparison of different soot generators: Towards a standard reference material for aerosol absorption
Publication type	Poster
Introduction & Background	Black carbon (BC) -or soot- aerosol particles are produced by incomplete combustion. They impact climate by absorbing radiation and are considered harmful, affecting human health in multiple ways. Different methods are available to quantify BC mass concentration. Most of these methods measure light absorption by aerosol particles either suspended or collected on a filter substrate and are globally used to monitor soot from different emission sources. The EMPIR BC project was triggered by discussions in the Gas Analysis Working Group (GAWG) of the Consultative Committee on Metrology in Chemistry and Biology (CCQM) to address the traceability of airborne BC absorption and to provide a standard reference BC material and a BC generation principle. One of the goals of the project is to provide a fresh-like BC source with a single scattering albedo (SSA) of 0.05 – 0.20 and an “aged” BC source with an SSA of 0.70 – 0.90. As part of the project activities, a soot generator workshop was planned by the consortium to compare the different available soot generators. The results presented here are an overview of the findings of this generator and BC soot comparison.
Methodology	Different generators including combustion-, spark-, and nebulization-based instruments, were compared during a workshop that took place in the aerosol physics laboratory of the Leibniz-Institut für Troposphärenforschung (TROPOS). A comprehensive set of aerosol analysis instruments was used to measure chemical and physical properties of the generated aerosol. The generators compared included mini-CAST 5203C (two different devices of the same model), 5201BC and 5303C (Jing Ltd), miniature inverted soot generator (Argonaut Scientific Corporation), a newly developed spark generator (FasmaTech), GFG1000 spark generator (PALAS GmbH), as well as nebulized suspensions of Aquadag®, fullerene soot and black monodisperse polystyrene particles. The particle number size distributions were measured with a scanning mobility particle sizer (SMPS, TROPOS). A polar nephelometer Aurora 4000 (Ecotech Pty Ltd.) was used to measure scattering coefficients. Absorption coefficients were measured at different wavelengths by a photoacoustic extinctiometer (PAX, DMT), a micro soot sensor (MSS, AVL), an Aethalometer (AE33, Magee Scientific), a multi-angle absorption photometer (MAAP, Thermo Scientific), four different cavity attenuated phase shift spectrometers (CAPS PMex and CAPS PMssa, Aerodyne Research Inc.). A tapered element oscillating microbalance (TEOM, Thermo Scientific) and a quartz crystal microbalance (QCM-MOUDI, TSI) cascade impactor were used to measure aerosol mass concentration.
Results & Conclusions	The aerosol geometric mean mobility diameters (GMD) measured during the workshop spanned from 50 to 200 nm for the different generators. The mini-CAST generators produced the smallest particles measured during the workshop (50 nm GMD and below). Spark ignition generated particles were in the range of 60 – 90 nm GMD. Nebulized Aquadag® exhibited a GMD of ~160 nm. The miniature inverted soot generator provided soot particles in the range of 150 – 200 nm GMD. The fullerene soot exhibited a bimodal number size distribution, in contrast to other sources.

	Preliminary analyses have shown that the SSA ranged from 0.01 to 0.33 (medians), at 870 nm wavelength. Combustion sources produced the aerosol with lower SSA values. Among combustion sources, the pre-mixed flame mini-CAST (5201BC) exhibited the lowermost SSA values, with an inter-quartile range (IQR) of 0.012 to 0.015 for the 75 nm particles. Two different mini-CAST 5203C devices were compared during the workshop. Both devices exhibited similar SSA values for the 100 nm particles. Spark generators exhibited comparable SSA values with IQR of 0.206 – 0.214, and 0.170 – 0.191 for the FasmaTech and PALAS, respectively. The nebulized Aquadag® and fullerene soot suspensions showed SSA values of 0.197 – 0.203 and 0.311 – 0.328, respectively. The generators investigated here can be potentially used as a standard reference material for BC absorption. Establishing a primary standard will require defining aerosol parameters such as (i) desired particle diameter, (ii) desired primary particle size and morphology, and (iii) desired optical properties, and determine the reproducibility and stability with which these parameters can be achieved.
Images	
Caption Figure 1:	 Single scattering albedo measured for the different soot generators at 870 nm wavelength

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Affiliation	AVL Ditest GmbH
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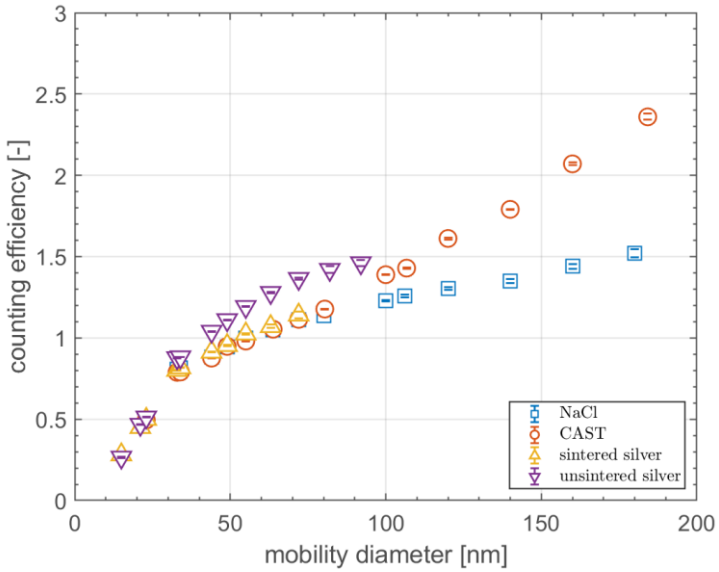
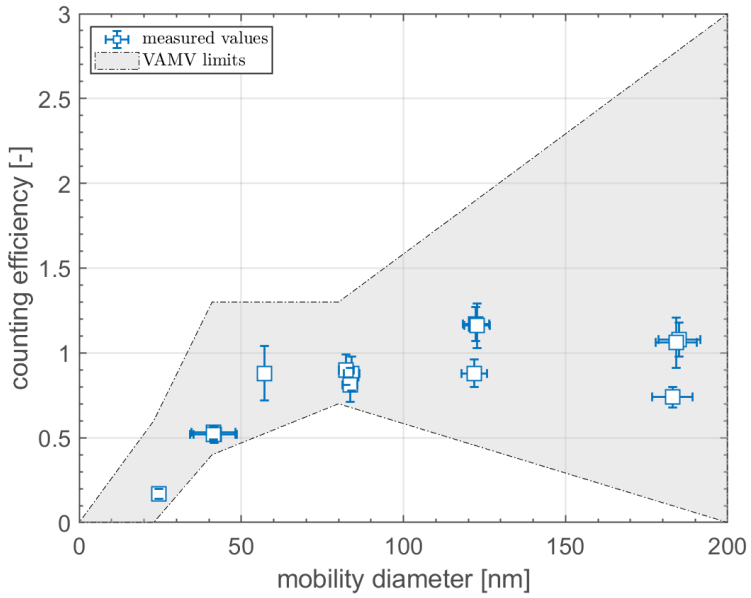
Coauthors	Tristan Reinisch; Alexander Bergmann
Publication title	Calibration of a particle number sensor for PTI measurements based on pulsed-mode diffusion charging
Publication type	Poster
Introduction & Background	Several European countries are about to implement particle number concentration (PN) measurements during periodic technical inspection (PTI) in order to monitor in-use conformity of diesel particulate filter (DPF) equipped vehicles. A measurement procedure with the intention to measure the solid PN fraction > 23 nm, with a respective instrument specification is currently under development by a New Periodic Technical Inspection (NPTI) group [1]. Above all, PTI sensors need to be affordable for the high number of inspection stations accredited for PTI (typically garages), and thus, different requirements compared to type approval instruments apply. Low manufacturing as well as maintenance costs are in the need of a simple and reliable calibration procedure to guarantee short lead times for a high number of units. Diffusion charging (DC) is an established, robust and low-cost sensor technology, suitable to realize measurement instruments for the detection of tailpipe particle number concentrations in the appropriate size (20 – 200 nm) and concentration regime (10^4 – 10^7 cm^-3). We developed a PN sensor for PTI measurements based on pulsed-mode DC [2]. The instrument is by default calibrated with NaCl particles, with a counting efficiency (CE) of 100% at 55 nm and a 50% cut-off at 23 nm. Dependency on material and morphology of the test aerosol may limit the applicability of simple calibration methods. We experimentally investigated the impact of test aerosol properties - material, size, concentration and morphology - on the CE of our instrument. We found that the CE is significantly influenced by particle material and/or morphology only for particles bigger than 80 nm, and thus conclude, that calibration with either of the used test aerosols below that size is reasonable. This conclusion is confirmed by a calibration of the instrument performed at METAS, using polydisperse CAST particles with varying mean size and concentration (5x10^3 – 7x10^5 cm^-3), whereby the CE criteria according to “Verordnung des EJPD über Abgasmessgeräte für Verbrennungsmotoren” (VAMV) [3] are easily fulfilled.
Methodology	In our test setup, the CE was measured for different monodisperse test aerosols (NaCl, CAST and sintered/unsintered silver particles) using a low-cut-off CPC as a PN reference. The instrument calibration was performed with NaCl particles at a size of 55 nm. Additionally, a calibration according to VAMV [3] was carried out at METAS with polydisperse CAST particles.
Results & Conclusions	The CE measured with all test aerosols is shown in Fig. 1. Results agree within 5% up to a particle size of 80 nm, except for unsintered silver particles. For bigger particles, significant deviations between CAST and NaCl particles are observed, which may be caused by the morphology, the material and/or by the different carrier gas. With the instrument, an additional calibration was performed at METAS using polydisperse CAST particles with different mean sizes and concentrations. Results, as well as limit values for the VAMV are shown in Fig. 2. Although a manufacturing calibration with NaCl particles has been performed before, CE criteria according to the VAMV [3] are easily fulfilled.

Images	
Caption Figure 1:	 Counting efficiency of measured with monodisperse particles of different material and morphology
Caption Figure 2:	 Counting efficiency measured at a calibration at METAS with polydisperse CAST particles

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Coauthors	Markus Dietrich ; Gerhard Haft ; Matthias Gaderer ; Hans-Peter Rabl
Publication title	Oxidation Kinetics Determination of GDI Engine Soot by a Radio-Frequency Sensor
Publication type	Poster
Introduction & Background	Since the introduction of the new exhaust-gas legislation Euro 6d-Temp, an increasing number of automobile manufacturers are installing Gasoline Particulate Filters (GPF) in the exhaust gas treatment. Although the law does not prescribe a monitoring of the GPF currently, the loading condition and functionality of the GPF has still to be examined. Therefore, the application of different sensor systems is possible. One of these sensors is a Radio-Frequency-Sensor (RF-Sensor). The composition of the aerosol from gasoline direct injection engines can differ for various conditions (bad fuel quality, cold start, Lambda different to 1). Several investigations [1,2] showed the variation in amounts and oxidation behaviour of Ash, Black Carbon (BC) and Volatile Fractions (VOF) for different engine conditions. In the investigation of Sappok [3] it was already shown, that ash had no influence on the signal for the RF-Sensor. Nevertheless, preliminary investigations on the test bench showed small differences in the sensitivity of the RF-Sensor for some engine settings under rich conditions (λ To investigate this finding more detailed, a high temperature oxidation furnace was modified to diagnose small GPF samples with the RF-Sensor. In addition to the already existing literature about the topic “diagnose of gasoline particulate filters”, these tests should help to identify differences in the sensitivity of the RF-Sensorfor different soot types (BC with and without VOF).
Methodology	A pipe system made of stainless steel with a mounting for a GPF sample was developed and integrated in a Linn-Electro-Oven to condition the samples. The GPF sample has a diameter of 1,85 inch and a length of 5 inch. In front and at the end of the GPF there is a modified RF-Sensor which is able to measure at higher temperature conditions inside of the furnace. For the test procedure, the sample is heated up externally by the furnace in a base gase of 2% O2 in nitrogen in a ramp up to 800°C. The GPF loading state is determined by the RF-Sensor and the downstream gas concentrations are measured by two mass spectrometers at the end of the pipe system. The utilized samples in the procedure were either with or without VOF components. These tests were performed for different engine operating points and engine conditions (cold start soot, middle load lambda 1, middle load lambda
Results & Conclusions	The data are currently being evaluated. [1] S. Choi ; H. Seong Oxidation characteristics of gasoline direct-injection (GDI) engine soot: Catalytic effects of ash and modified kinetic correlation https://doi.org/10.1016/j.combustflame.2015.02.004 [2] M. Bogarra et. al. Gasoline direct injection engine soot oxidation: Fundamentals and determination of kinetic parameters https://doi.org/10.1016/j.combustflame.2017.11.027 [3] A. Sappok In-Use Particulate Filter State of Health Monitoring: Prognostics and Diagnostics using Radio Frequency Sensing http://www.nanoparticles.ch/archive/2017_Sappok_PR.pdf

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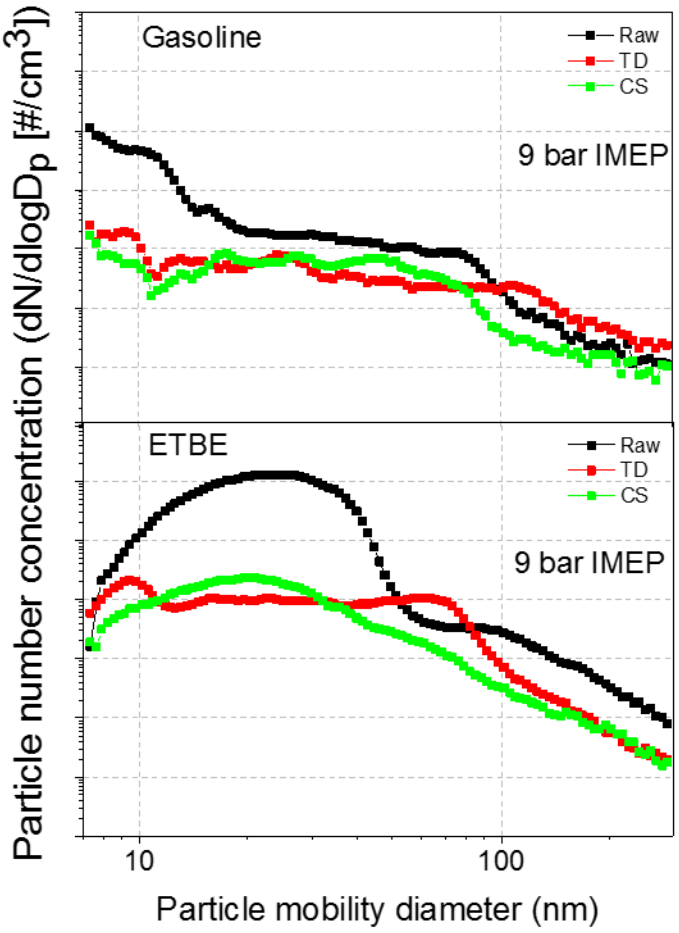
Publication title	Particle Size Distribution and Semi-Volatile Components from Gasoline and Oxygenated Fuels
Publication type	Poster
Introduction & Background	The objective of the study was to characterize particulate from GDI engine with respect to two different fuels with different oxygen content a two operating conditions. The semivolatile components were analyzed by comparing un-treated particle size distributions with sample using a thermal denuder and a catalytic stripper. Moreover, the un-treated particulate emissions were loaded on a HC adsorber for the different engine operation conditions. These samples were analyzed using GC-MS to identify different hydrocarbon species. Gasoline is increasingly blended with renewable fuels, including alcohols, in order to reduce CO2 emissions. However, Particulate Matter (PM) emissions has been shown to correlate with illness and mortality. The health effects of PM emissions is depending on both size and chemical composition. Thus it is of interest to study the hydrocarbon when using renewable fuels.
Methodology	A single cylinder 0.5 dm3 engine was operated at 2000 rpm at two load points of 4.5 and 9 bar IMEP. Particulate characterization was performed using SMPS and particle loading was done on a HC adsorber column. One thermal denuder and one catalytic stripper, maintained at 250° C, was used in parallel with the un-treated exhaust. The exhaust sample was diluted with heated, external air flow. Particle loading was performed at controlled temperature (60°C using a HC-adsorber (ORBO 49P from Supelco) and the sampling flow rate was maintained at 15 l/m. The samples were analyzed using GC-MS. GC-MS results were later compared with the particle size distributions.Oxygen content of baseline fuel was 3.6%(v/v) and ETBE was 22 %(v/v).
Results & Conclusions	The figure above shows the particle size distribution for two test fuels at 9 bar IMEP including the stripped samples using the thermal denuder and the catalytic stripper. Particle size distribution was found to be relatively higher for raw emissions for both the test fuels and results from TD and CS were found to be nearly similar. The sample using ETBE fuel showed more volatile components compared to gasoline at 9 bar IMEP. By comparing the HC species from GC-MS, the Volatile HC could be attributed to oxygenated hydrocarbons.
Images	

Caption Figure 1:



Particle number size distribution at 9 bar IMEP

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Publication title	Using Machine Learning to Investigate Ultrafine Particle Emissions from Arriving Aircraft at Near-Airport and Background Sites
Publication type	Poster
Introduction & Background	Ultrafine particles (UFP;
Methodology	Particle number concentration (PNC; a proxy for UFP) was measured continuously on selected weeks at six sites along an arrival path between April and September 2017 at 1-sec resolution. For this same monitoring period, flight activity data were acquired from the U.S. Federal Aviation Administration, which included three-dimensional positions of aircraft at ~5-sec resolution, and meteorology was acquired from the U.S. National Weather Service station at Logan Airport at a 1-min resolution. Data were averaged to each hour; PNC was natural-log transformed prior to averaging. We used random forest regression to identify key covariates and optimize prediction of PNC. Each tree was grown by a bootstrap sample with random subsets of predictors selected at each split. Final models were based on the average results of all trees.
Results & Conclusions	Preliminary models explained 53-68% of 1-hr natural-log transformed PNC variance. Relative humidity and wind speed typically explained most of the PNC variability at both near-airport and background sites. While meteorological variables were ranked most important, flight frequency of aircraft landing on the study runways increased in model importance when comparing the 95th and 99th percentile models to the 50th percentile at near-airport sites. Similar trends were observed at a background site >15 km away from the study runways (R2 = 0.54-0.68). Our results suggest that landing aircraft can help explain peak ambient UFP exposures. Machine learning can be a tool to understand how these aircraft contribute to community-level PNC and understand the spatial extent of these exposures.

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Publication title	Impact of emissions from fossil fuel and biomass burning on ambient concentrations of black carbon (BC) in the Milan metropolitan area
Publication type	Poster
Introduction & Background	In this study, spatial and temporal variation of black carbon (BC) concentrations originating from two major combustion sources, i.e. fossil fuel combustion and biomass burning, were evaluated at two sites in the metropolitan area of Milan – one site was in the city centre, primarily impacted by urban emissions, and the other site was at Bareggio, a sub-urban area located 14 km to the west of Milan.
Methodology	Sampling was conducted from summer 2017 to winter 2018. Using the Aethalometer model, sources of BC were apportioned based on the measurements performed using seven-wavelength (AEE33) and single-wavelength (AEE51) aethalometers in Milan and Bareggio sampling sites, respectively
Results & Conclusions	Our measurements demonstrated higher average biomass combustion-generated BC concentrations at the Bareggio site (2763 ± 1050 ng.m-3) in comparison to the Milan site (1921 ± 876 ng.m-3). The Aethalometer model suggested a slightly higher annual average contribution of BC originated from fossil-fuel combustion (%BCff) in Milan (84.9 ± 5.4%) than in Bareggio (±4.1%); however, contributions from biomass -burning originated BC (%BCbb) were considerably higher in Bareggio (e.g., a wintertime average of 61.3±5.3%) than in Milan (e.g., a wintertime average of 30.5 ± 4.6%). Furthermore, %BCff trends showed a peak during the morning and afternoon rush hours in both Milan and Bareggio, when the highest traffic activities are expected. On the other hand, a nighttime peak was observed for %BCbb when emissions from residential wood burning for heating purposes was prominent. Although traffic is still a major source of combustion-generated BC particles in the metropolitan Milan, our findings revealed the significant role of emissions from the residential wood burning on ambient BC concentrations in that area

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Publication title	Characterization of Collected Aerosol Carbonaceous Particles using Atomic Force Microscopy
Publication type	Poster
Introduction & Background	Atomic Force Microscopy (AFM) can be employed for study of various individual or agglomerated particles (Klapetek, P., Valtr, M., Nečas, D., Salyk, O., Dzik, P. (2011). Atomic force microscopy analysis of nanoparticles in non-ideal conditions. Nanoscale research letters, 6(1), 514.). In this contribution, collected aerosol carbonaceous particles were studied by AFM on flat surface.
Methodology	Carbonaceous particles were prepared by different methods (combustion, electrical discharge), collected and studied by AFM (Bruker Dimension Icon). AFM data were processed using free scanning probe microscopy data analysis software Gwyddion (David Nečas, Petr Klapetek, Gwyddion: an open-source software for SPM data analysis, Cent. Eur. J. Phys. 10(1) (2012) 181-188).
Results & Conclusions	Presented poster will include measured and processed AFM data of carbonaceous particles together with detailed description of production process of those particles.

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Coauthors	Florian Dahlkötter, Thomas Krinke, Torsten Tritscher
Publication title	Measurement of ultrafine particle emissions from passenger cars
Publication type	Poster
Introduction & Background	Discrepancies between emissions over a driving cycle and real measurements in operation show the need for an emissions test. Exhaust aftertreatment systems (diesel particulate filters) may fail due to ageing, poor maintenance, poisoning or manipulation. Opacimeters are too insensitive to detect DPF errors in the latest vehicle generations. Germany decided to introduce particle number limit values for periodic exhaust emission testing for diesel vehicles on 1.1.2021. Measuring systems with condensation particle counter (CPC) have been used in the past for the type approval of new engines according to EURO 5b/6. Recently these systems have also been applied to test vehicles in real operation (RDE).
Methodology	The measuring system that is proposed is designed in such a way that only solid soot particles are measured: - Sampling probe with immediate dilution with dry air prevents condensation of water - 1 µm cyclone with water trap prevents large particles or water droplets from interfering with the measurement or contaminating the measuring system - Catalytic Stripper removes volatile components - Condensation particle counter detects and counts each individual particle. A working liquid (isopropanol) is used to convert the particles into much larger droplets and measure them with optical light scattering. ISO 27891 [4] describes the traceable calibration of CPCs which has been implemented for PEMS measurement systems from JRC.
Results & Conclusions	Recent measurement results from campaigns in Belgium and The Netherlands will be shown. In conclusion we present a measuring device for particle number concentration in exhaust gas for use in workshops and test centres. The use of the proven CPC measurement technology means: - Maintenance-free measuring system (period ≥ 1 year) - Direct counting of each individual particle in the exhaust gas - Comparable and reliable results due to traceable calibration according to ISO 27891 - Future-proof technology also suitable for gasoline vehicles and stricter requirements - Comparability with results of type approval and measurements in real operation (PEMS-RDE)

	Streibel Thorsten
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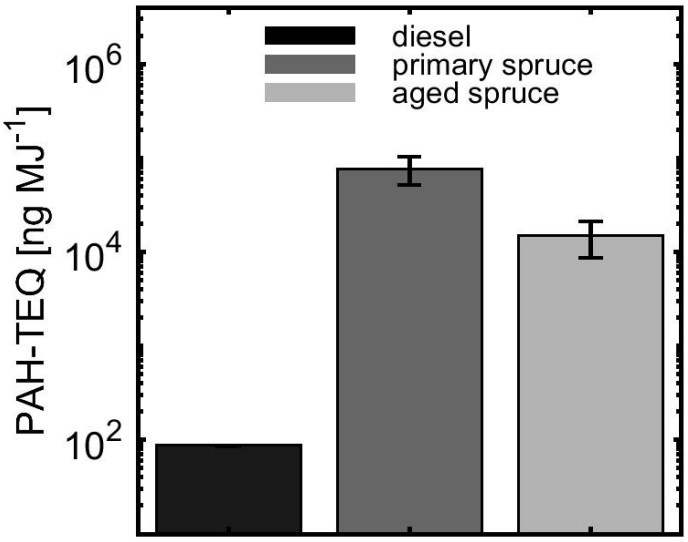
Publication title	Implications of photochemical ageing for source apportionment and health effects of wood combustion aerosol
Publication type	Poster
Introduction & Background	The combustion of logwood in residential stoves has been identified as substantial contributor to local air pollution. It releases high levels of particle-bound polycyclic aromatic hydrocarbons (PAH) and oxygenated PAH (OPAH), in the range of 0.1% - 1% of the total emitted particulate matter (PM). However, in the atmosphere those compounds undergo chemical transformation along with physical transformation of PM, which changes the toxicity of wood combustion emissions. Degradation kinetics of particle-bound PAH and OPAH are mainly affected by the particle composition and microstructure. Gas phase PAH, in contrast, have higher differences in reactivity with OH, O3 and NO3 and are less affected by direct photolysis.
Methodology	In this study, we aged combustion aerosol from spruce logwood with a recently described high-flow oxidation flow reactor, “Photochemical Emission Aging flowtube Reactor” (PEAR) (Ihalainen et al. (2019), Aerosol Science & Technology). We investigated the effect of ageing on emissions of PAH and OPAH as well as PAH diagnostic ratios for emission source identification. Moreover, genotoxicity of primary and aged emissions were assessed in 4 h in vitro exposures of A549 cells by comet assay. Finally, carcinogenity of the emissions based on PAH toxicity equivalent (PAH-TEQ) was determined and compared to emissions from a non-road diesel engine as reference for carcinogenic emissions “group 1”.
Results & Conclusions	The combustion of spruce logwood released 404 µg MJ-1 of 35 analysed PAH, 317 µg MJ-1 of 11 analysed Oxy-PAH and 12.5 µg MJ-1 of 5 analysed OH-PAH, most of which are known potential mutagens and carcinogens. Photochemical processing by PEAR substantially degraded particle-bound PAH, which was also reflected in declining PAH-TEQ by 45 to 80% per equivalent day of photochemical ageing. However, the wood combustion aerosol would require more than four days of photochemical ageing to reach comparable TEQ of diesel exhaust particles, a carcinogen of “group 1”, from a 24.5 kW non-road diesel engine. Compared to PAH, OPAH were less affected by photochemical ageing, while OH-PAH increased due to secondary formation. Genotoxicity increased significantly from clean air control to both primary and aged aerosol as assessed by comet assay, but without quantitative differences in genotoxicity between primary and aged spruce combustion aerosol. However, in-depth transcriptome analysis revealed different gentoxic mechanisms and induced DNA damage. Diagnostic ratios to identify wood combustion emissions in ambient air remain stable during photochemical ageing for PAH species PHE/ANT, FLA/PYR, RET/CHR, and IcdPYR/BghiPER. On the other hand, BaP/BeP and BaA/CHR allow monitoring of the photochemical age. This study motivates more detailed investigation of the consequences of photochemical ageing on toxicity and identification of wood combustion emissions in ambient air.
Images	

Caption Figure 1:	 PAH-TEQ referred to benz[a]pyrene for diesel combustion as well as primary and aged spruce wood combustion emissions.

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Publication title	The effect of fuel applied on the chemical composition of PM generated in combustion processes – the preliminary case study
Publication type	Presentation
Introduction & Background	From the physical and chemical (or even mechanical) point of view, the combustion processes of organic fuels occurring both in furnaces and combustion chambers of vehicular engines never run with emission of a mixture of carbon dioxide and water vapour as the result. Exhaust gas consists of hundreds (or even thousands) of groups of chemicals and limits for some of them tried to be regulated by the global polices. The remaining part of exhaust gas components is not limited. Moreover, among raw exhaust components gaseous chemicals and solid particles may be distinguished. The components of solid particles - depending on the conditions of the combustion processes - may occur both in gaseous and PM-bound forms. These aspects cause studies on exhaust emission to constitute a great challenge for chemists and engine designers. The paper aimed at the determination of chemical characterisation of particulate matter emitted as a result of combustion of different fuels type in both stationary and linear sources.
Methodology	The samples of particulate matter collected during solid fuels combustion in domestic heating unit and during emission tests on dyno and engine test beds were analysed for the presence of elemental and organic carbon, inorganic ions, metalloids and metals, including heavy metals. The content of analysed chemicals differed depending on the emission source. The most significant difference was visible in domestic and industrial coal combustion. The applied systems of exhaust after-treatment in energy plant caused the removal of carbonaceous fraction remaining the mineral components of particulate matter. Organic carbon, chloride and mercury were the most characteristic for domestic coal burning. The eco-pea coal was characterized by the presence of sulphate ions.
Results & Conclusions	The most significant difference was visible in domestic and industrial coal combustion. The applied systems of exhaust aftertreatment in energy plant caused the removal of carbonaceous fraction remaining the mineral components of particulate matter. Organic carbon, chloride and mercury were the most characteristic for domestic coal burning. The eco-pea coal was characterized by the presence of sulphate ions. Acknowledgements The work was completed as a part of the research subvention at AGH University of Science and Technology (no. 16.16.210.476) with substantive and financial support of the Institute for Sustainable Energy and by means of the infrastructure of the Center of Energy, AGH UST in Kraków.

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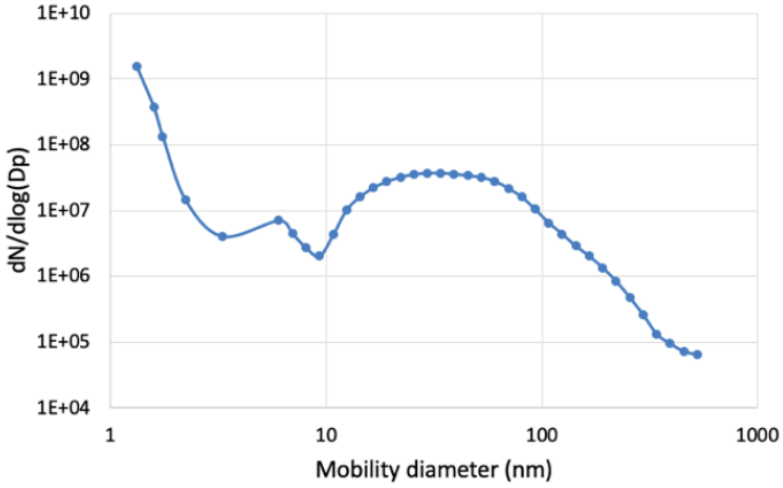
Publication title	High number concentration of non-volatile sub-3nm aerosol particles emitted by gasoline direct injection engine
Publication type	Poster
Introduction & Background	Previous measurements of aerosol particle size distribution from an exhaust of different types of internal combustion engines have shown that particle emissions of the very smallest particles in the size range of 1-3 nm can be very substantial (Rönkkö et al. 2017, Giechaskiel et al. 2017). There is also evidence that for example for natural gas engines these particles are not all volatiles (Alanen et al. 2015). In diesel engines the issue of high aerosol particle number emissions has been addressed by introducing emission limits already in 2009. In recent years also the gasoline engine got emission limits for type approval phase.
Methodology	The investigation was carried out on a 4-stroke single cylinder SI engine equipped with the cylinder head of a naturally aspirated GDI engine. A six-hole injector is located between the intake valves. A port fuel (PFI) injector was located in the intake duct. The engine was equipped with a three-way catalyst (TWC). The engine was run at two engine speeds, 2000 and 4000 rpm, chosen as representative of the typical driving conditions. A smoke meter (AVL 415S) was used for measuring the filter smoke number (FSN) which was converted in mass concentration through an empirical relation. Particle number concentration and size were measured in the range from 1 to 560 nm by means of an Airmodus A11 nano Condensation Nucleus Counter (nCNC) in parallel with a TSI® engine exhaust particle sizer (EEPS). For particle number measurement the exhaust was sampled and diluted by means of the a Dekati® engine exhaust diluter (DEED), a PMP -compliant engine exhaust conditioning system. The dilution ratio was fixed at 1:79. A 1.5 m heated line was used for the sampling of the engine exhaust in order to avoid the condensation of the combustion water.
Results & Conclusions	Figure 1 presents an example of a particle number size distribution during a GDI engine run at steady state condition at 4000 rpm. It can be seen that the highest number concentration is in the size range of 1-3 nm in particle diameter. Also, a prominent soot mode is visible with a modal size of about 40 nm. With 2000 rpm engine speed, no particles in the size range of 1-3 nm were emitted by the engine. Theoretical diffusion losses for the sampling lines and the Dekati DEED diluter are taken into account in the calculations based on Vanhanen et al. 2017. The size distribution is measured after the TWC and the evaporation tube between the two dilution stages of the DEED was heated up to 400oC. The results show that in addition to the dry soot mode at around 40 nm, a very pronounced cluster mode is visible even if the evaporation tube is used. When comparing the measurements done without the evaporation tube it was found that most of particles in the size range of 1-3 nm don't evaporate in 400oC temperature and the volatile particle fraction in this measurement was around 30%.
Images	

Caption Figure 1:	 Figure 1. Aerosol particle number size distribution from 1 to 560 nm measured from exhaust of a GDI engine running at constant engine speed of 4000 rpm.

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Publication title	Metrology for mitigating adverse health effects from airborne particulate pollutants: the EMPIR AeroTox project
Publication type	Poster
Introduction & Background	Atmospheric particulate pollution has been linked to a broad spectrum of adverse health effects including respiratory problems, cardiovascular diseases, cancer and dementia. These effects depend not only on physical, but also on chemical properties of airborne particulate matter (PM) though to date it has proven difficult to disentangle the relative contribution of PM constituents to the reported population-level health effects. We propose the use of “tailored” reference aerosols, combined with high-resolution optical imaging of exposed cells and state-of-the-art cell analysis methods to study the cytotoxic effects of airborne PM in vitro in a systematic way to help inform which PM metrics are associated with the induction of toxic mechanisms that can be linked to specific health effects.
Methodology	In this project (2019-2022) we will demonstrate a new method for studying health effects based on well-defined reference aerosols generated in the laboratory. Synthetic ambient aerosols of different complexity (from single to multiple component mixtures) will be generated in a systematic way and used for controlled exposure of biological models. This systematic approach will enable us to correlate the effects of isolated PM constituents with the in vitro toxicological response observed across biological models. The in vitro to in vivo correlation will be substantially improved by i) developing novel methods for cell/tissue exposure to aerosols, which simulate the in vivo inhalation route and ii) developing and validating more physiologically relevant in vitro and ex vivo models that mimic ongoing in vivo processes in the lung. The investigation of cellular response to chemical stressors will be considerably extended by examining not only panels of known markers in endpoints such as inflammation, oxidative and genotoxicity but also employing untargeted proteomic and transcriptomic methods to examine the global cellular response to the synthetic aerosol particles. This will allow investigation into novel and potentially component-specific pathways. To study how aerosol particles penetrate into the cells and interact with subcellular compartments, novel image-analysis tools going beyond conventional computer vision and utilising the latest developments in unsupervised learning will be developed. Finally, by building on experience developed during the early phase of the project we will carry out the first imaging intercomparison to establish the level of agreement in image-based assays of aerosol toxicity, providing a benchmark for the development of future protocols and standards.

Results & Conclusions	This presentation aims to summarize the goals of the EMPIR AeroTox project, which will begin in June 2019, in order to encourage and invite contributions from the community.

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Publication title	Investigation of the effects of humidity and volatile coatings on the photothermal interferometry signal
Publication type	Poster
Introduction & Background	Measurement artefacts can heavily influence the accuracy of traditional filter based measurements of ambient aerosol light absorption and hence the determination of equivalent black carbon concentration (eBC). Some of these artefacts are always present, while others are dependent on the local ambient conditions and properties of the aerosol particles, thus making their correction difficult. One example of such an artefact is the presence of water or other volatile substances in the sample. These volatiles are adsorbed onto the filter matrix, increasing the transmission and reducing the measured light absorption. (Nessler et al., 2006) Alternatives to filter based methods are in-situ measurement techniques, which measure light absorption of the aerosols directly. Two examples of in-situ measurement techniques are the well-known photoacoustic devices and the considerably less well-known photothermal interferometry (PTI) based instruments. Both techniques suffer from many fewer artefacts than traditional filter based methods and are able to measure light absorption accurately even when aerosol light scattering dominates. Artefacts caused by volatile aerosol coatings, however, remain an issue. In the case of resonant photoacoustics the artefact can be quite severe and lead to considerable underestimation of the eBC. This occurs due to the dynamics of latent heat consumption and release in the aerosol. Instead of transferring the absorbed energy directly to the surrounding gas as a photoacoustic signal, the volatile coating on the particle evaporates, consuming the energy as latent heat. Recondensation then occurs upon cooling, which results in the release of a secondary photoacoustic signal out of phase with the primary excitation and a damping of the resonant photoacoustic signal. (Raspet et al., 2003; Langridge et al., 2013)
Methodology	As PTI also measures the energy transferred from the light absorbing particles to the surrounding gas, this time in the form of temperature, PTI measurements are subject to the same measurement artefact. However, as the technique does not rely on resonant amplification of the signal, the temporal evolution of latent heat effects can be determined. These effects are observed as a reduction of the rate of temperature increase of the gas surrounding the particles during the heating period and a delayed or reduced rate of cooling between heating periods.
Results & Conclusions	We have performed initial experiments exploring this artefact and investigated methods of quantifying its effect with PTI. In these measurements a hygroscopic solution containing Nigrosin was nebulised and used as a test light absorbing aerosol. By varying the humidity of the aerosol the latent heat artefacts can be measured as a function of the water content of the particles. Here we compare the results with an equivalent dry aerosol and discuss methods of extracting information on the volatile content of ambient aerosols from PTI measurements.

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Publication title	Detection of nanoparticles in workplace using inexpensive instrument based on ionization-type smoke detector
Publication type	Poster
Introduction & Background	The potential of a simple, inexpensive instrument based on ionization type smoke detector to detect excessive concentrations of nanoparticles in workplace is examined here. Smoke detectors using light scattering and ionization chambers are widely used in households and industry in many countries. They have been also proposed for air quality monitoring (Litton C.D., et al., Aerosol Sci. and Tech., 2014, 38:1054–1062), with light scattering used in many inexpensive instruments, despite having meaningful sensitivity to particles larger than several hundreds of nm. In an ionization chamber, ions created by radioactive decay are depleted by aerosol particles, with the resulting signal being roughly representing the total particle length concentration, similar to the signal of diffusion charging instruments, and relatively close to the lung-deposited surface area, providing for a signal with reasonable relevance to human health. Ionization type instrument has been previously proposed for diesel exhaust measurement (Vojtisek-Lom, J of Air and Waste Manag. Assoc., 2011, 61:126-34.) with a detection limit on the order of million of particles per cm3 (p/cm3), sufficient to detect absence or gross failure of diesel particle filters.
Methodology	In this study, a compact hand-held unit comprising a measuring ionization chamber, batteries, electronics and a microprocessor has been fabricated and subjected to comparison testing using several types of nanoaerosols. As selecting a narrow range of particle sizes using a differential mobility analyzer did not yield concentrations detectable by the novel nanodetector, comparisons were done on heterogeneous aerosols of different concentrations and mean particle diameters. Generation of nanoaerosols at concentrations sufficiently high to be detected by the new instrument and sufficiently stable to be evaluated by a reference instrument was challenging and a combination of reference and fast-response instruments (scanning and fast electric mobility sizers) has been used.
Results & Conclusions	The novel nanodetector was able to detect 30-40 nm mean diameter latex particles at low hundreds of thousands of p/cm3, 30-50 nm mean diameter ammonium sulfate particles at medium hundreds of thousands of p/cm3, and 40-100 nm mean diameter soot particles at low hundreds of thousands of p/cm3. The results suggest that inexpensive ionization type detectors are capable of detecting nanoparticles at levels above hundred or several hundreds of thousands p/cm3. Due to the general absence of a suggested occupational limit for nanoparticle concentrations and due to vast differences and uncertainties in health hazard potential of individual nanomaterials, the authors are not making any inference as to the suitability of the observed detection limit; the typical urban background is on the order of ten thousands of p/cm3, with momentary excursions to hundreds of thousands of p/cm3 primarily due to motor vehicles and mobile machinery. Supported by the Technology Agency of the Czech Republic (TG01010135).

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Publication title	Portable Exhaust Toxicity System Concept: Compact Air-liquid Interface Exposure System for Dynamic Engine Operation
Publication type	Poster
Introduction & Background	The adverse health effects arising out of exhaust inhalation stem primarily from fine particulate matter, semivolatile organic compounds and reactive nitrogen species, out of which only some are subject to the type approval legislation or even scrutiny during non-regulatory measurements. While no agreement has been reached on a commonly accepted metric for ultrafine particles or health effects, several groups have been pursuing evaluation of the health risks of combustion and industrial aerosols by controlled exposure of models of human lung air-liquid interface to conditioned exhaust. Commercial and research exposure systems exist, some of them validated and fairly compact, but in many studies, cold start and dynamic operation, both associated with high emissions of health-relevant compounds, are not addressed, and if so, a constant dilution ratio is used for transient conditions. This study presents a working concept of a compact system striving to be usable both in the lab and in real world operation.
Methodology	Raw exhaust is diluted by either a proportional sampling partial-flow gravimetric system or a rotating disc diluter, enriched to approximately 5 % CO2, and fed to online monitoring instruments and into a toxicological incubator operating at 37 C. The exhaust is passed through a heat exchanger and a membrane humidifier filled with deionized water, raising humidity to 85-95 %, and divided into exposure boxes running at 200 cm3/min. In each exposure box, sample is evenly divided into eight streams, each leading to an insert with cellular model, with inserts placed in a standard 24-well plate. In an identical parallel path, a second set of cellular models are exposed to filtered air as control. In order to preserve the contribution of gaseous and particle phase to the health effects, particle losses have been minimized by keeping the sample path short and conductive, but no effort was taken to artifically augment the particle deposition rate. Preliminary evaluations were carried on a direct injection spark ignition engine installed on an engine dynamometer and fitted with active cooling allowing one dynamic cold-start test analogous to the World Harmonized Light Vehicle Test Cycle (WLTC) to be run every two hours.
Results & Conclusions	Preliminary results suggest repeatable particle concentrations which are comparable, after correcting for dilution ratio, between dilution by proportional sampling system and rotating disc diluter, with discerned effects of cold start. Particle losses assessed by total particle count were in low tens of percent and are expected to be lower with improvements to the membrane humidifier. Toxicity assays suggest that multi-day tests comprised of two cold-start and additional warm-start WLTC tests per day are feasible. While the system has not been used on the road, the experiences so far suggest that on-board air-liquid interface exposure device of comparable or slightly larger size and complexity compared to „traditional“ on-board monitoring systems, is technologically feasible, moving the real driving emissions assessment to even more health relevant level. This work was supported by the Czech Science Foundation grant no. 18-

	04719S: Mechanisms of toxicity of gasoline engine emissions in 3D tissue cultures and a model bronchial epithelial cell line.
Caption Figure 1:	 Exposure box for cellular models on standard well plate.

	Walter Stefanie
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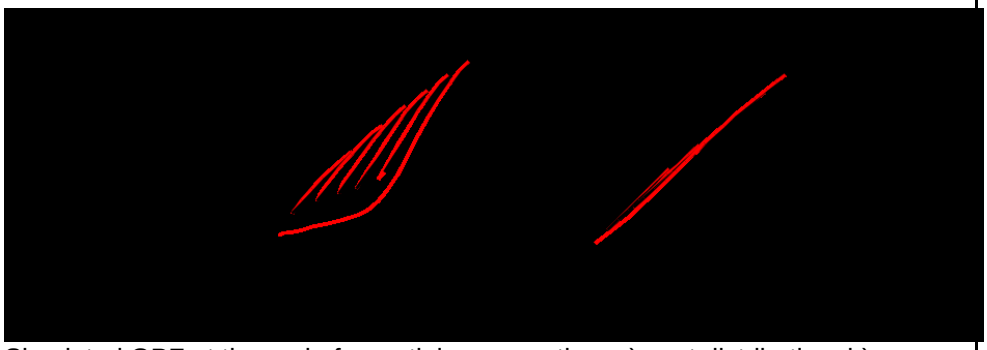
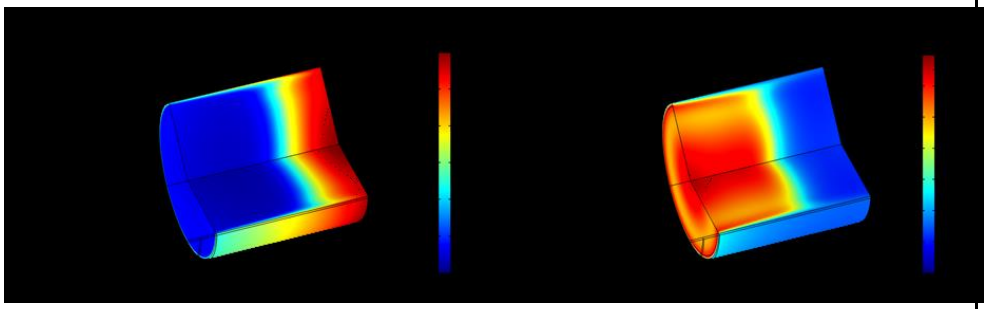
Publication title	Simulative Modelling of the Location Dependent Soot Distribution in Gasoline Particle Filters and their Influence to the Soot Mass Determination by Radio Frequency and Differential Pressure Sensors
Publication type	Poster
Introduction & Background	Up to now, gasoline engines have been able to meet emission standards without particulate filters, as the combustion of petrol produces much smaller and lighter particles compared to diesel engines and only the particulate mass has been regulated. Due to more stringent emission limits and the regulation of particle numbers, gasoline particulate filter (GPF) have been serialized for many vehicles. To control the soot loading of DPFs in serial applications, often the pressure drop over the filter is evaluated. A further option for filter monitoring is a radio frequency-based approach that detects the deposited soot directly via its conductivity (RF sensor). However, a transfer of the existing knowledge to GPFs is limited due to changed soot properties and boundary conditions (e.g., different regeneration procedures). In order to be independent of complex measurements to improve the sensors for GPF applications, a simulation model was developed in this paper. This allows a deeper insight into the behavior of both sensor systems.
Methodology	In order to enable a realistic description of the entire filter system, the areas downstream and upstream of the GPF as well as the GPF itself were FE-modelled with COMSOL Multiphysics. Due to the fine structure of the filter channels it is not possible to simulate them in detail considering the computing time. For this reason, the GPF is treated as a homogeneous porous medium. The description of the location-dependent mass flow through the GPF is based on the pressure difference between inlet and outlet channels using the Darcy law, which considers the permeability of the filter walls and the deposited soot. In order to take into account the local distribution of the soot load, the trajectories of soot particles up to their entry into the GPF channels were simulated. It was shown that due to their low mass, particles follow the gas flow almost perfectly. Therefore, it was assumed in the following simulations that the deposited soot is proportional to the specific mass flow through the GPF.
Results & Conclusions	With the simulation model it is now possible to observe the soot distribution as well as the flow conditions in all operating modes. Figure 1 shows them at the end of a partial regeneration. The simulations clearly show that soot burn-off mainly takes place in a narrow front. This also has a considerable influence on the mass flow through the GPF. Both effects can possibly affect the accuracy of the RF sensor and the differential pressure system. The simulated sensor signals during soot loading, interrupted by several partial regenerations, are shown in figure 2. When loading the empty GPF, both the RF sensor and the differential pressure signal provide a signal linear to the soot mass. During subsequent partial soot burn-offs, however, a clear advantage of the RF sensor becomes apparent. There is almost no hysteresis during each loading and regeneration. In the differential pressure measurement, on the other hand, a strong decrease in back pressure can be observed at the beginning of every regeneration. With these results, both sensor systems can be systematically optimized and adapted to the special conditions of GPFs.

Images	
Caption Figure 1:	 Simulated GPF at the end of a partial regeneration; a) soot distribution; b) exhaust gas flow through the filter walls.
Caption Figure 2:	 Simulated sensor behavior of (a) the differential pressure and (b) the resonance frequency fres of the mode TE111 evaluated with the RF sensor during six times loading the GPF 3 h long with a soot loading of 1 g/h (displayed in black) following a 25 s long regeneration with an exhaust gas containing 1 % O2 (in red). After the last loading, the filter was almost completely regenerated.

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Publication title	Highly selective formaldehyde detection with zeolite membranes for indoor air quality monitoring
Publication type	Poster
Introduction & Background	Certain volatile organic compounds present in aerosols are potentially hazardous for human health. Formaldehyde (FA), for instance, is proposed as a tracer for indoor air quality monitoring due to its carcinogenic nature. The recommended exposure limit should not exceed 100 ppb challenging portable devices in terms of sensitivity and selectivity. Chemo-resistive metal-oxide sensors made by flame spray pyrolysis (FSP) are quite attractive as they can detect sufficiently low FA levels, offer fast response and recovery times and can be produced cost-effectively. However, they lack selectivity.
Methodology	Here, we propose a modular sensor system that overcomes this limitation by placing a highly selective membrane for aerosol pre-separation upstream of a highly sensitive chemo-resistive sensor. The membrane consists of a supported zeolitic membrane that is hydrothermally grown in a stainless steel autoclave (Fig. 1a). The resulting membrane is coin-type with a diameter of 16 mm (Fig. 1b). Zeolites are microporous materials with a pore size comparable to the molecular dimensions of volatile compounds, thus, ideal for a pre-separation of the gas mixture. They are widely applied in catalysis and large-scale molecular separations. FSP-made SnO2 nanoparticles, that are deposited on sensor substrates via thermophoresis (Fig. 1c), form a highly porous film which is used as detector. These detectors are wire-bonded onto a chip carrier for the integration into the electric circuit (Fig. 1d).
Results & Conclusions	This modular system exhibits excellent selectivity to carcinogenic formaldehyde over ethanol, ammonia, acetone and isoprene (all > 100) at realistic 50% relative humidity. Moreover, relevant formaldehyde concentrations down to 30 ppb are selectively detected with a high signal-to-noise ratio (> 70), despite significantly higher interfering gas levels. Response times below 10 min are sufficiently fast considering recommended formaldehyde exposure time guidelines. This modular membrane-sensor concept can be tailored to target other pollutants and may constitute a new class of highly sensitive and selective detection systems for indoor air quality monitoring.
Images	

Caption Figure 1:	

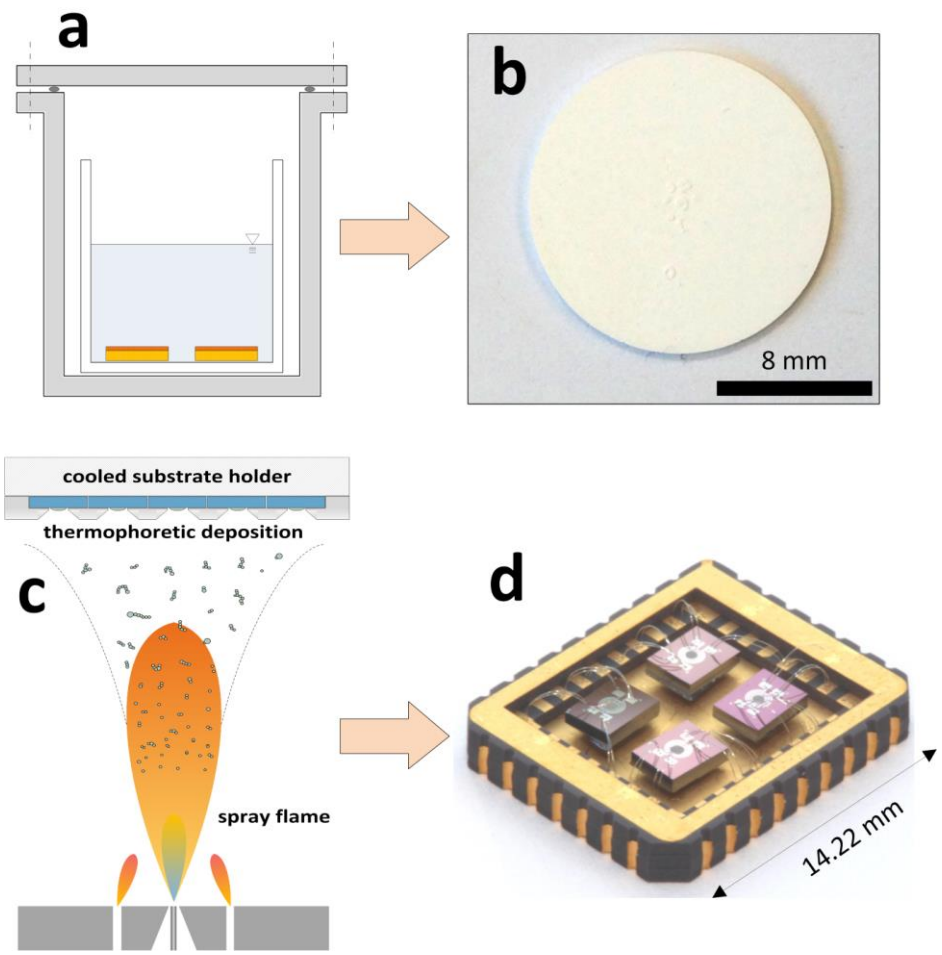

Figure 1. (a) Zeolitic membranes are hydrothermally grown on supports and (b) are of coin-type shape with a diameter of 16 mm. (c) Sensors are produced by flame spray pyrolysis and (d) are bonded onto a chip carrier for electrical integration. Placing the membrane upstream the sensor result in a highly selective formaldehyde detection system.

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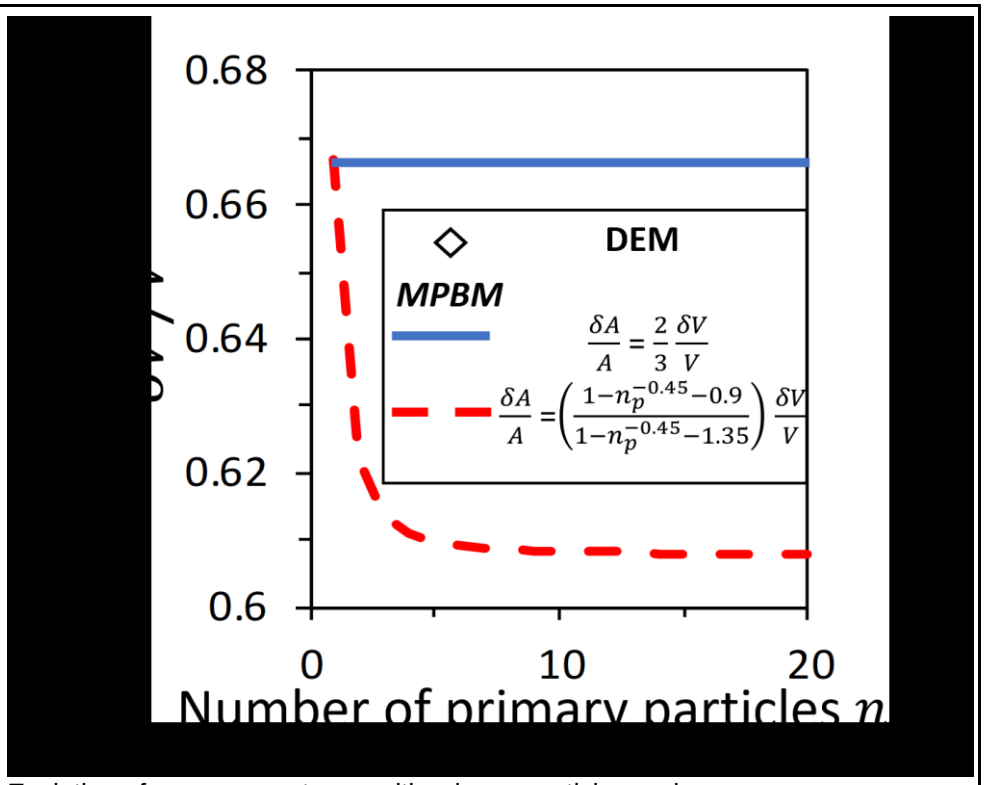
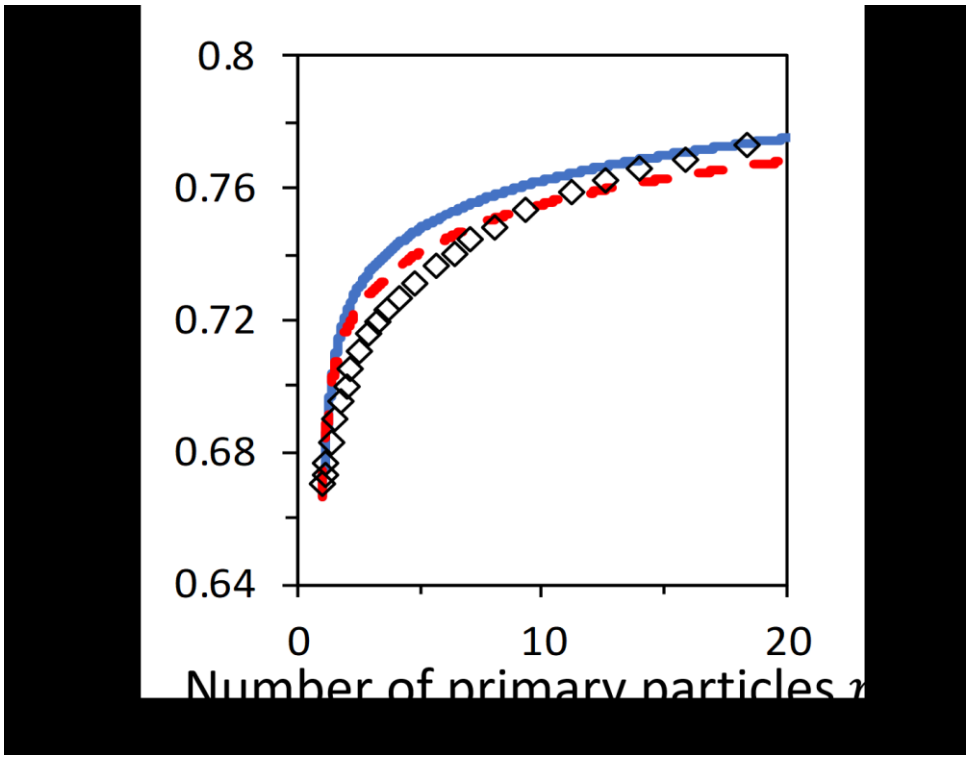
Publication title	Evolution of surface fractal dimension during coagulation and surface growth with a monodisperse population balance model
Publication type	Poster
Introduction & Background	Predicting the evolving surface area of fractal-like nanoparticles during coagulation and surface growth is challenging due to necking (chemical bonding) between primary particles and formation of aggregates. Surface fractal dimension (D_s) can be used as a shape descriptor to distinguish chemically bonded aggregates from physically bonded agglomerates and scales the surface area (A) with the volume (V) of a nanoparticle [1].
Methodology	Here a three equation monodisperse population balance model (MPBM) is used to simulate nanoparticle coagulations and surface growth and is benchmarked with detailed Discrete Element Modelling (DEM) [3]. The MPBM tracks number density, total volume and area of the nanoparticles and solves an additional equation to predict D_s [2] that varies between 2 and 3. The source term for change in the area during surface growth is calculated for agglomerates [3] and aggregates [2,4] to investigate its effects on D_s.
Results & Conclusions	As shown in Figure 1a, the ratio of change in area to change in volume for agglomerates stays constant and equal to 0.667 as the number of primary particles per agglomerate increase. However, for aggregates, as the number of primary particles per agglomerate increase it drops sharply from 0.667 and asymptotically reaches 0.607. Despite these differences in the scaling of the area source term with that of volume between aggregates and agglomerates, the MPBM is able to reproduce D_s within ~3% of DEM derived values, as shown in Figure 1b. This suggests, that the calculation of D_s is relatively insensitive to the differences between the area source terms used. A simplified description of the evolving area during surface growth is therefore capable of predicting D_s with only a small error, while a more elaborate formulation of the area source term may not benefit the overall accuracy of a MPBM enough to justify the additional complexity. [1] Balthasar, Frenklach. Combust. Flame. 2005;140:130-145. [2] Kelesidis, Goudeli, Pratsinis. Carbon. 2017;121:527-535. [3] Tsantilis, Kammler, Pratsinis. Chem. Eng. Sci. 2002;57:2139-2156. [4] Mueller, Blanquart, Pitsch. Combust. and Flame. 2009;156:1143-1155.
Images	

Caption Figure 1:



Evolution of area source terms with primary particle number n_p.

Caption Figure 2:



Evolution of shape descriptor D_s/3 with primary particle number n_p. Both area source terms can reproduce the surface fractal dimension within ~3% relative error.

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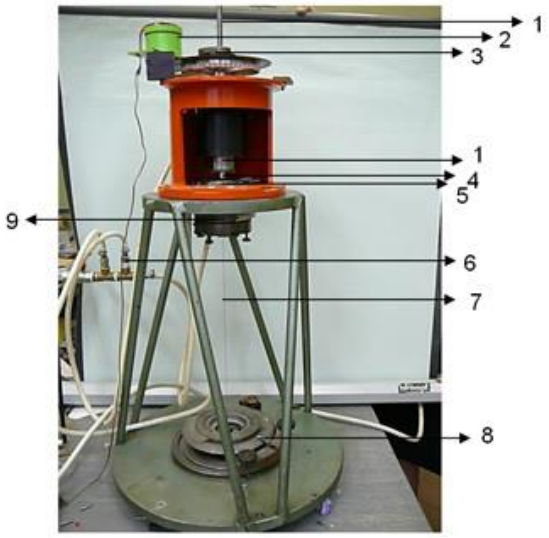
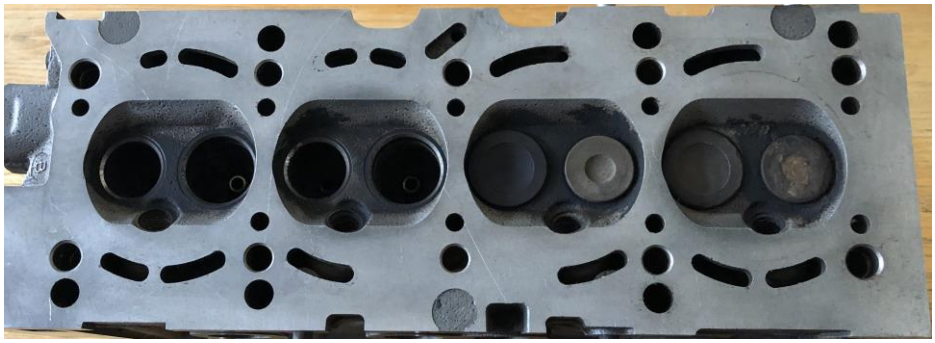
Publication title	The effect of TiO2 amount in engine oil on composition of carbon deposits and the friction coefficient in the contact zone between them and valve head material
Publication type	Poster
Introduction & Background	The modern SI combustion engines contain valvetrains with camshafts often driven from the engine crankshaft through a chain transmission. The steel valves made with seat inserts made of alloyed steel. The friction between them is often boundary or mixed one. During operations of engine some amount of engine oil reaches the combustion chambers and combustion of it can results in carbon depositions on cylinder head and valves surfaces. Such carbon deposits can also deposite on seats of valves and their inserts. The aim of the study was to evaluate the effect of TiO2 nanoparticles content in engine oil on the composition of carbon deposits on valve seats and to check the friction coefficient between such deposition and steel valve heads.
Methodology	The studied engine operates under lubrication by the mixture of engine oil 10W-40 with 2 wt% amount of TiO2 nanoparticles delivered by SIGMA-ALDRICH. The oil was mixed with the TiO2 commercial product using the High-Speed Planetary Mixer THINKY SR-5000. The oil was then treated with ultrasonic waves in the GT Sonic VGT-800 Ultrasonic Cleaner for only 2 min. With the SI engine placed in Fiat Punto it was made 500 km milage in different road conditions. After dismontage of the engine cylinder head, the original outlet valves were taken from it and their heads with carbon depositions deposited on them were cut to allow placement in the SEM microscope and tribotester holders. The SEM microscope measurement can show occurence or lack of TiO2 naoparticles in the carbon deposites. The tribotester used for measurement of the spin friction torque was used to estimate friction coefficient between steel ball and carbon deposits deposited on the valve head in conditions of no lubricant.
Results & Conclusions	It was observed the occurence pof TiO2 peak in the SEM courses obtained for composition carbon deposites on valve head surfaces. The results from the measurement of friction showed, that the increasing of loading of contact zone resulted in increase of friction torque but also in decrease of friction coefficient between steel ball and valve head deposided by layer of carbon depositions.
Images	

Caption Figure 1:	 Test bench for determination friction coefficient
Caption Figure 2:	 Cylinder head from Fiat Punto 1.2 8v

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Publication title	Emissions characteristics for data analysis methods of Light-Duty Diesel vehicle on Real Driving Emissions Test
Publication type	Poster
Introduction & Background	NOx and Particulate Matter, which are serious problems in the emission of light-duty diesel vehicles. So, Government in every country establishes standards for vehicle emissions to decrease the NOx and Particulate Matter and improve air quality. Although NOx among various emissions are consistently strengthened, it is the largest difference between the certification test and real driving test. Therefore, South korea and Europe executed RDE-LDV, which measures and regulates air pollution on real-road using the PEMS from September 2017.
Methodology	EC-JRC had studied possibility of RDE test and evaluation method from 2011 to 2013, finally EC-JRC announced “RDE 2nd package” in 2016. The contents about evaluation subjects, procedures and methods of RDE-LDV were mostly confirmed in the “RDE 3rd package” in June 2017. MAW and Power-binng were used as evaluation methods in RDE 2nd and 3rd packages. In addition, the EC is examining and discussing the final RDE 4th package that improved the existing real driving test method. Also, The method of real driving test will be revised. It is evaluated by applying the Evaluation Factor to the emission amounts of exhaust gas.
Results & Conclusions	The researchers carried out Real Driving Emissions test on real-road from 2015 applying Euro 6b to 2018 applying Euro 6d-temp. Exhaust emissions of vehicles in 2016 and 2017 with LNT or SCR systems as after-treatment equipment to comply with the Euro 6b regulations have been over-regulated. After RDE-LDV was introduced, Exhaust emissions of vehicles combined after-treatment systems were measured less than regulation standard. As emission regulations have been strengthened, exhaust emissions have been significantly reduced.

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Publication title	Sensing Solution for Airborne Carbon Nanotube and Carbon Black Exposure based on Raman Spectroscopy
Publication type	Poster
Introduction & Background	Whereas carbon nanotubes (CNTs) are known as engineered nanomaterials that form under specific conditions in a flame environment, there is sufficient evidence that diesel combustion process can also generate CNTs [1]. In addition to the carcinogenic properties of diesel soot [2], the potential presence of CNTs in diesel emissions represents an increased risk of adverse health effects due to the high aspect ratio and biopersistence of CNTs [3]. In vivo studies indicate that inhaled CNTs can travel to the lungs and enter circulation, causing pulmonary effects including inflammation, granulomas and pulmonary fibrosis [4]. As a result, the National Institute of Occupational Health and Safety (NIOSH) in USA recommends an exposure limit of 1 µg/m3 of CNTs as a respirable mass, in addition to a permissible exposure limit of 3500 µg/m3 for carbon black as an 8-hour time-weighted average concentration [5]. Detecting such small amount of CNTs in the environment, as well as distinguishing it from other combustion particles is extremely challenging with the current sensing solutions.
Methodology	Here, we would like to present a wearable, cost-effective air sampler equipped with environmental sensors that optimize the working performance [6]. The sampler collects airborne particles from the surrounding atmosphere, performs size separation using an air-microfluidic channel and collects the respirable fraction on one disposable membrane filter and the remaining particles on another [7]. At the end of a workday of sampling, the sampler is placed inside a bench-top sized reader which retrieves the filter, scans collected samples on the membranes autonomously using Raman spectroscopy and reports exposure. The exposure is based on the mass of collected particles based on a predefined library created using the same materials and the sampled volume of air.
Results & Conclusions	The system enables detection of sub-nanogram quantities of CNTs and nanogram quantities of carbon black by utilizing the advantages of Raman spectroscopy, and has the ability to uniquely distinguish particles of interest from background aerosols present in air. Using this approach, material-specific, long-term exposure monitoring of both occupational and ambient exposure becomes possible. Similar monitoring solutions are also available optimized for detecting different contaminants such as respirable crystalline silica, nanocellulose and other materials.