Analysis & Characterization of spray coating related nano-particle exposures

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Background & Objectives NanoGeCo

Nanoparticle generation by atomization processes in spray coating (http://www.nanogeco.eu/)

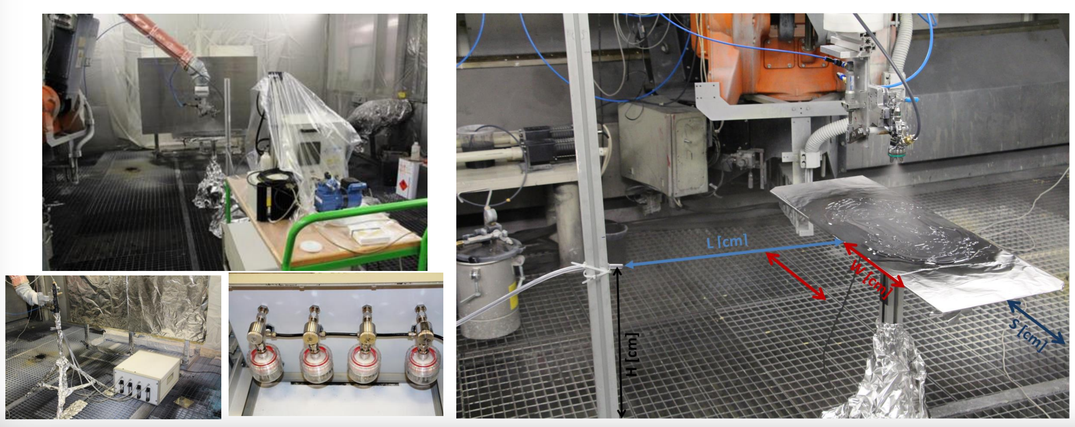
Background:

- Increasing application of manufactured nanomaterials (MNM) in industrial products requires knowledge about environmental & human safety – MNM such as carbon nano-tubes, TiO2, ZnO etc. are important paint material components
- In spray coating processes, a large fraction of paint overspray remains airborne & may pose health risks

Main objectives:

- Detailed analysis on the generation & fate of nanoparticles by atomization processes in spray coating
- Overspray particle concentration measurements using different coatings with & without MNM, different spray guns, different spray rates, dilution & exposure conditions
- Sampling was performed at different inlet positions to be used in the framework of CFD simulations and droplet evaporation

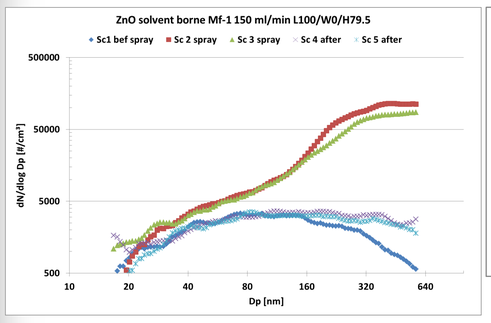
Approach & experimental set-ups

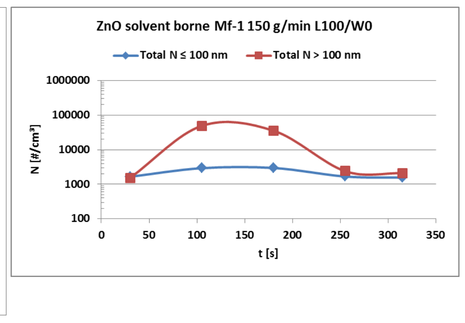


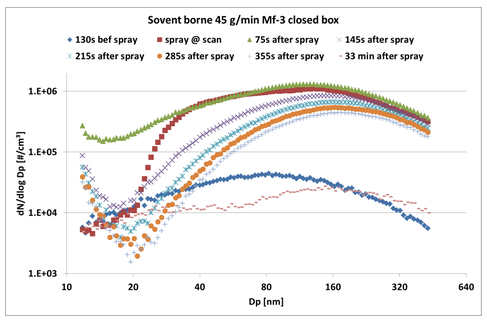
Experiments were mainly performed in a spray booth ventilated from ceiling to base with 0.3 m/s. The monitoring focused on Particle Size Distribution (PSD) using an SMPS at several inlet positions. Mass sampling on filters for different size fractions and later SEM/EDX analysis was performed, see **Fichera et al. EAC 2017**. In some experiments simultaneous SMPS/ELPI measurements were performed. Usually during an experiment 5 PSD scans with the SMPS were performed, the 1st scan before spray was to monitor the lab background, the 2nd & 3rd scan were performed during spray application, thereafter a 4th & 5th scan followed (no spray).
A control experiment was performed using a wooden box of approx. 1 m³ volume. Paint was sprayed into the closed wooden box through a thrilled hole.

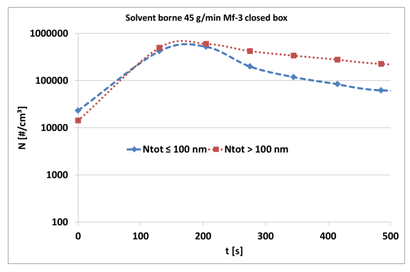
Main Results

Impact dilution conditions –ventilated spray booth vs closed box



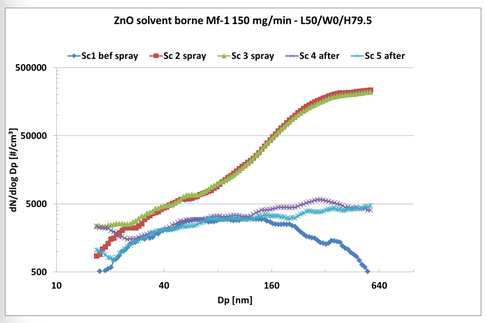


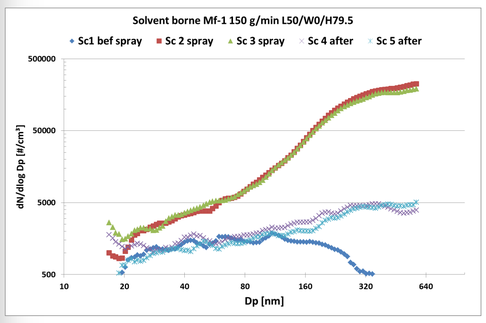




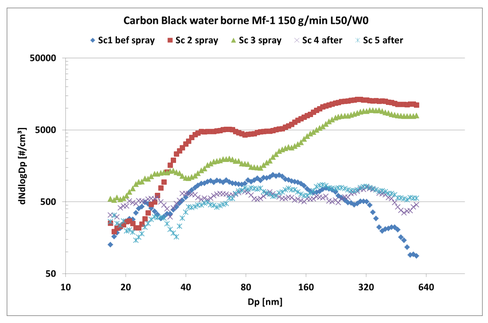
- Ventilated chamber: highest particle number concentrations (PNC) during spray application Scan (Sc) 2 & 3 – immediate drop towards background levels when spray application stops (scan 4 & 5 after) due to mixing & downward transport
- Closed box experiments – slow & aerosol dynamics driven evolution of PSD (condensation, coagulation & wall deposition), UFP (≤ 100 nm) PNC

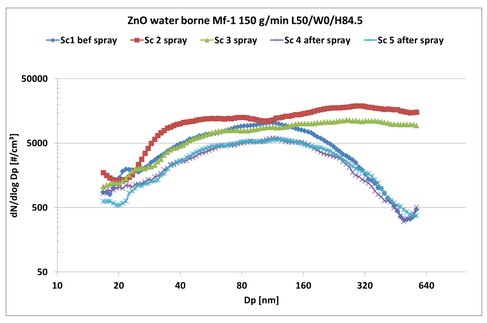
Solvent borne w/ & w/o MNM Mf-1



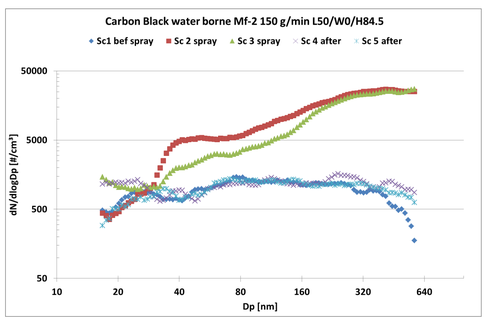


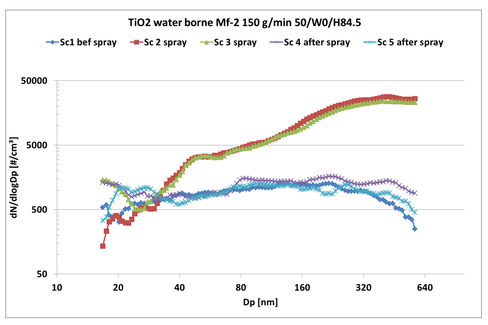
Water borne w/ & w/o MNM Mf-1



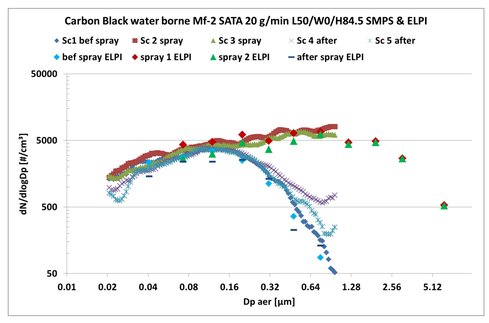


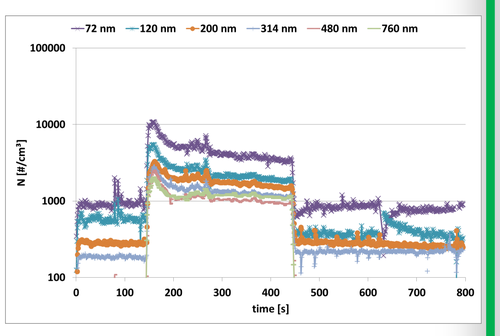
Water borne w/ & w/o MNM Mf-2

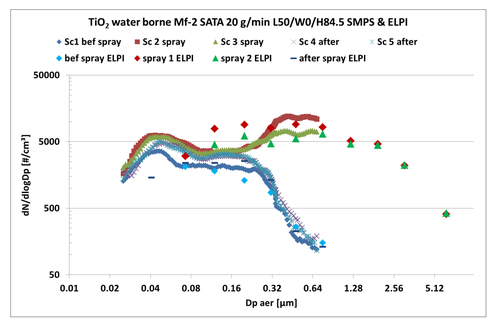


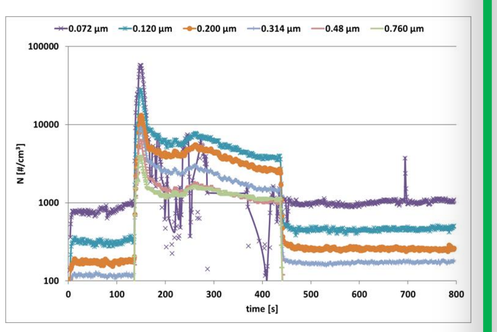


Water borne MF2 simultaneous SMPS/ELPI Measurements

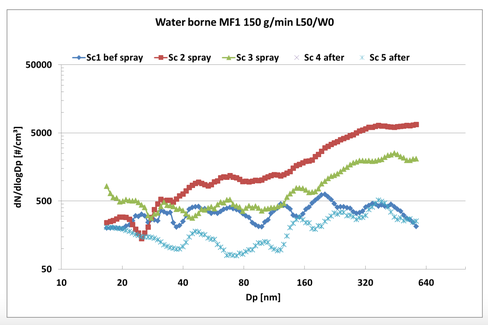


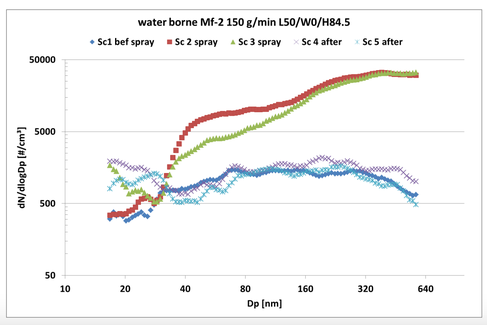






- Solvent borne coatings with & w/o MNM resulted in far higher PNC than water borne coatings
- The tested water borne coatings showed an extremely “sticky” behaviour
- Different behaviour possibly due to different dynamic viscosity at atomization





- PSDs of Sc 3 (2nd scan during spray app) show frequently lower PNC than previous one Sc 2 for water borne coatings due to pre-coating of the spray target & similar at the instruments impactors
- By using effective densities of 2.3 g/cm³ for Carbon Black & 3 g/cm³ for TiO_2 MNM ≤ 120 nm D_{p_aero} a fair match between SMPS and ELPI measurements resulted
- ELPI time series indicate the strong dynamics at the begin of the spray process, a strong increase within a few seconds is followed by a an exponential decrease while spraying - coagulational scavenging may explain these effects
- ELPI measurements show distortions for D_{p_aero} ≤ ~70 nm

Conclusions

Sensitivity of different parameters on nano-particles (in number)**:**

impact ↑

- **Dilution** & **transport** are fundamental parameters impacting upon overspray UFP & nano-meter sized particle exposures
- **Coating type/solvent** water vs solvent borne is of fundamental importance - Solvent borne PSD 1 to 2 orders of magnitude higher PNC than water borne
- **Impact of MNM**
- Pre-coated surface vs clogging at impactors (SMPS & ELPI)
- Duration of spray process
- Higher spray rate results in higher PNCs

- ELPI & SMPS time series show that at begin of spray coating process PSD are dominated by UFP
- Large PNC level in 300 nm to 2.5 µm range, SEM/EDX analysis shows MNM agglomerates surrounded by liquid phase within this size range
- Due to high PNC in the 300 nm to 2.5 µm size range - coagulation & scavenging may inhibit larger UFP concentrations
- Generally different shape of ELPI & SMPS measured size distributions - good match can be obtained by using effective densities for coatings with TiO_2 & nanotubes

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