Karlsruhe Institute of Technology

Institute for Technical Chemistry (ITC)
Department Aerosol and Particle Technology

Characterization of nanoparticles and polymer nanocomposites in flames for subsequent studies on health effects

N. Teuscher[1], M. Hufnagel[2], W. Baumann[1], M. Hauser[1], S. Mülhopt[1], M. Berger[4], C. Schlager[4], T. Krebs[4], M. Garcia-Käufer[3], R. Gminski[3], N. Wingert[3], A. Hartwig[2], H.-R. Paur[1], D. Stapf[1]

[1]Institute for Technical Chemistry, Karlsruhe Institute of Technology, Karlsruhe, 76021, Germany
[2]Institute for Applied Biosciences, Karlsruhe Institute of Technology, Karlsruhe, 76021, Germany
[3]Institute for Infection Prevention and Hospital Epidemiology, Universitätsklinikum Freiburg, Freiburg, 79106 Germany
[4]Vitrocell Systems GmbH, Waldkirch, 79183, Germany

ProCycle

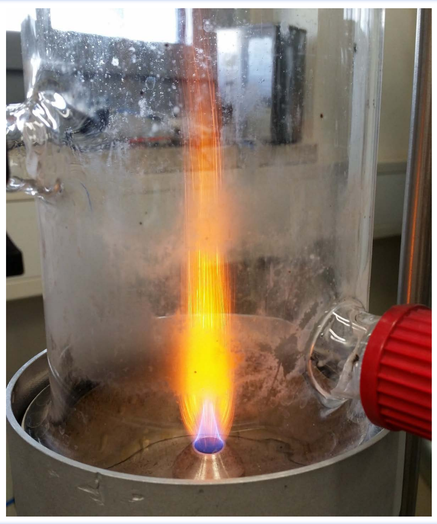
Background

- Nano-enabled thermoplastics are widely used and their end of life potentially inherits a risk for human health and the environment by release of engineered nanomaterials (ENMs)
- The possible end of life scenarios, recycling and thermal treatment, are investigated
- Comparison of the combustion products of nano-enabled thermoplastics, ENMs and pure thermoplastic matrices

Laboratory setup with Vitrocell® Automated Exposure Station, ELPI and tube burner.

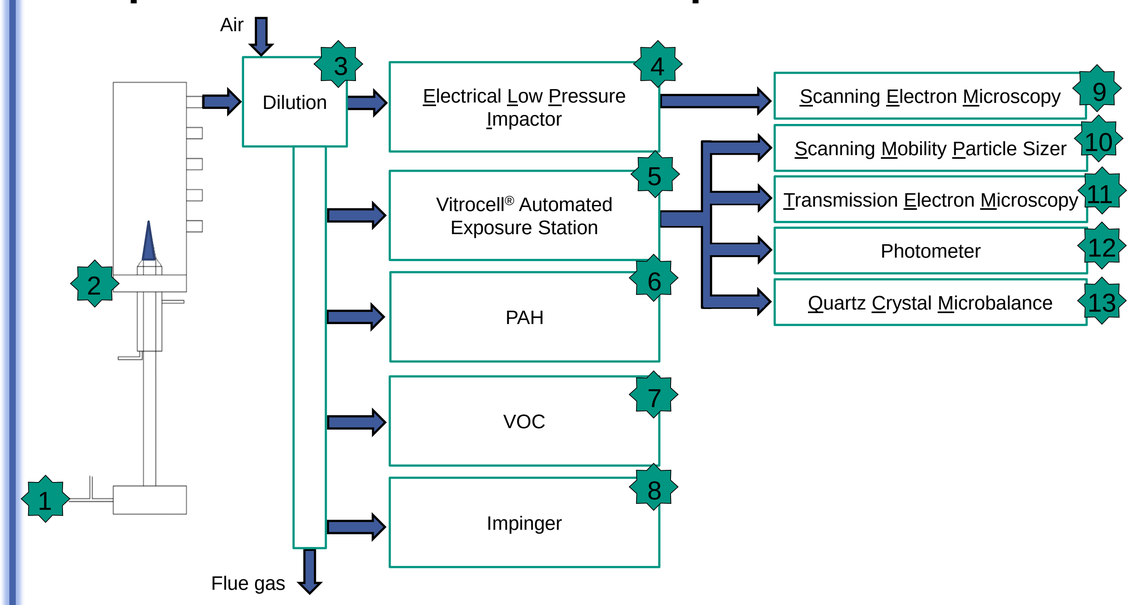
Tube burner

- Laminar premixed Ethylene / Air flame
- Stoichiometry: 0.8 < λ < 1.2
- Adiabatic flame temperature: ~ 2100 °C
- Addition of suspensions or dusts possible
  - Nano metal oxides
  - ground nano-enabled thermoplastics
  - carbon fibres
- Sampling at five different heights above the burner
- Adaption of a dilution stage allows the installation of various measurement systems



Tube burner with addition of ground nano-enabled thermoplastics.

Set up and measurement techniques

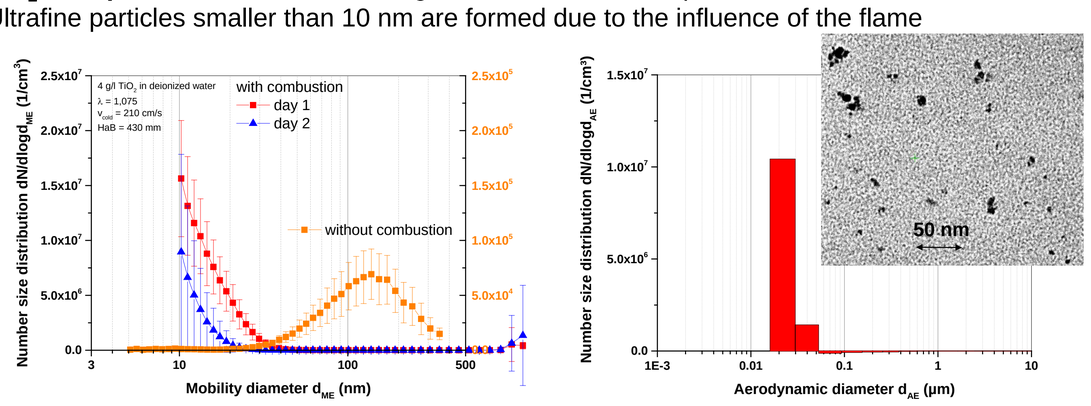


Experimental setup with installed measurement techniques.

1. Polymer nanocomposite powders (< 315 µm) or suspensions of pure nanoparticles are aerosolized and added to an lean Ethylene / Air mixture
2. Tube burner: Combustion of the gas/particle mixture
3. The combustion products are diluted and characterized via different measurement techniques
4. ELPI: number size distribution between 10 nm and 10 µm
5. Vitrocell® Automated Exposure Station:
   - online air/liquid interface exposure of A549 cells
   - Size selective inlet and aerosol conditioning to 37 °C and 85 % relative humidity
   - Increased deposition rates by applying a high voltage
   10. SMPS: number size distribution between 10 nm and 1000 nm; measurement inside the reactor of the exposure station
   11. TEM: image analysis of grids in an exposure chamber
   12. Photometer: inline measurement of number concentration upstream of each exposure chamber
   13. QCM: Online dose monitoring
6. PAH: Analysis of the polycyclic aromatic hydrocarbons by HPLC and fluorescence detection
7. VOC: Analysis of the volatile organic compounds via TD-GC-MS
8. Impinger: subsequent ecotoxicological studies

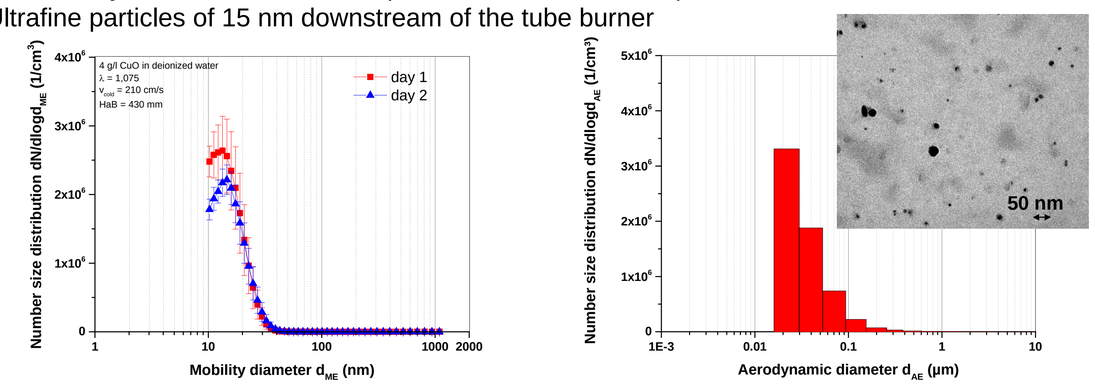
Measurement of combustion aerosols

- **TiO_2 nanoparticles** are used as a negative control for the experiments with A549 cells
- Ultrafine particles smaller than 10 nm are formed due to the influence of the flame



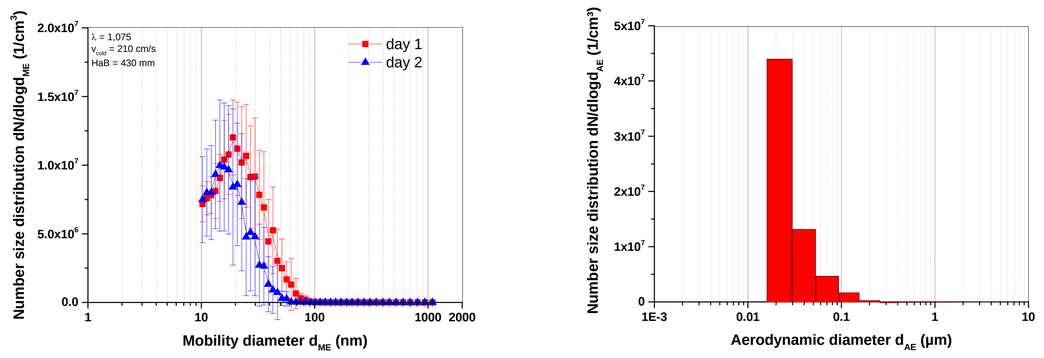
Size distribution of TiO_2 nanoparticles with and without combustion. Left: SMPS measurements of several experiments. Right: averaged ELPI measurement of an 4 hour experiment. Insert: TEM image.

- **CuO nanoparticles** are used as a positive control for the experiments with A549 cells
- Ultrafine particles of 15 nm downstream of the tube burner



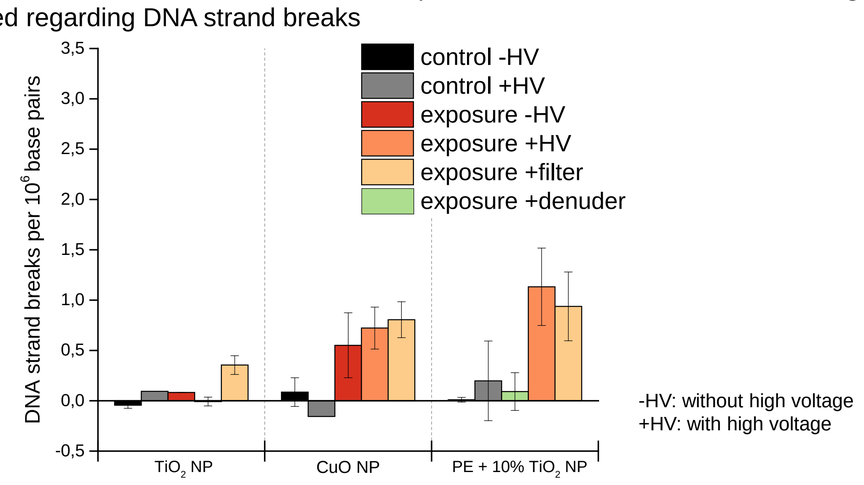
Size distribution of CuO nanoparticles with combustion. Left: SMPS measurements of several experiments. Right: averaged ELPI measurement of an 4 hour experiment. Insert: TEM image.

- The **Polyethylene + 10 % TiO_2** nanocomposite is tested in comparison to the pure nanoparticles and pure matrix
- Ultrafine particles of 30 nm downstream of the tube burner



Size distribution of particles from the combustion of Polyethylene + 10 % TiO_2. Left: SMPS measurements of different days. Right: averaged ELPI measurement of an 4 hour experiment.

- After 4 h exposure to the combustion aerosol and 20 h post-incubation the **A549 human lung cells** were analysed regarding DNA strand breaks



DNA strand breaks in A549 cells induced by released aerosols from incinerated thermoplastics and related ENMs.

Conclusions and Outlook

- Comprehensive characterization of the combustion aerosol of nano-enabled thermoplastic was achieved
- Pure nano metal oxides and nano-enabled thermoplastics form ultrafine nanoparticles with high number concentrations in an Ethylene / Air flame
- Combustion aerosols of nano-enabled thermoplastics induce DNA strand breaks in A549 cells
- For PE + 10 % TiO_2 the toxicity is due to gaseous species
- The influence of the gas phase on the toxicity of aerosols will be tested by using a denuder

Acknowledgement

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