Karlsruhe Institute of Technology

ANALYSIS AND TOXICOLOGICAL EVALUATION OF DUSTS FROM RECYCLING AND THERMAL DECOMPOSITION OF NANOCOMPOSITES AND STRATEGIES FOR RISK MINIMIZATION - PROCYCLE

ProCycle

Behavior of Nanoparticles and Polymer Nanocomposites during Lab-scale Combustion within the Project 'ProCycle'

Nadine Teuscher*, Werner Baumann, Manuela Hauser, Sonja Mülhopt, Hanns-Rudolf Paur, Dieter Stapf
Institute for Technical Chemistry / Karlsruhe Institute of Technology / Eggenstein-Leopoldshafen / Germany
*Corresponding author: nadine.teuscher@kit.edu

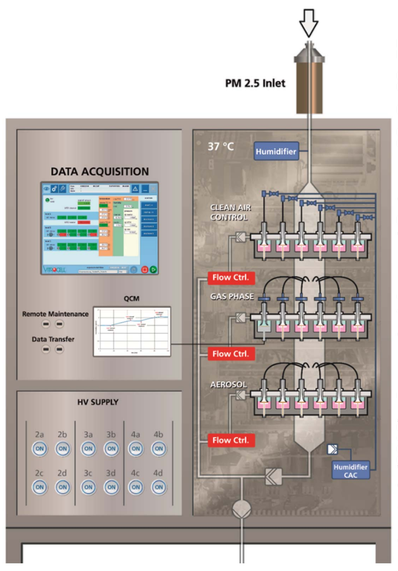
Further ProCycle Posters
09.06, 15.03, 15.33

Background

- Nano-enabled thermoplastics are widely used and their end of life potentially constitutes 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

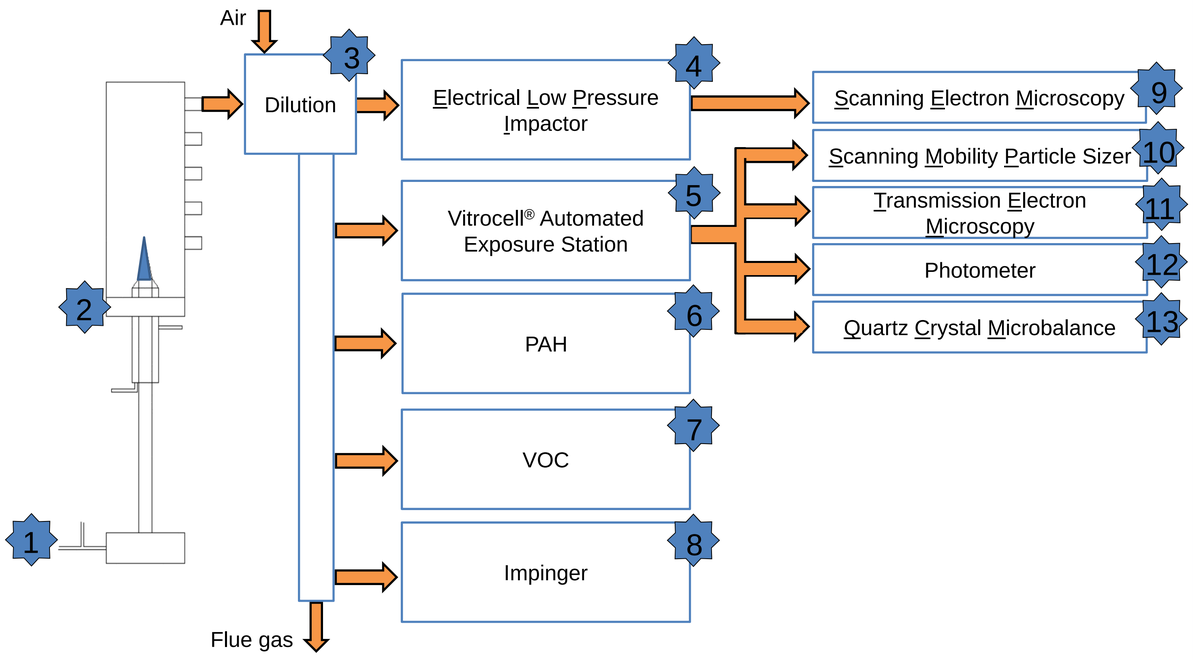
Vitrocell® Automated Exposure Station

Specification	
Cell exposure	3 x VITROCELL® 6/4 CF stainless steel modules of 6 well format, 1 x 6/3 CF stainless steel modules of 6 well format (Clean Air Control)
Aerosol	• Direct aerosol sampling via size selective inlet: $PM_{2,5}$ inlet with 1 m^3/h • Aerosol conditioning to 37 °C and 85 % relative humidity.
Negative control	Humidified synthetic air
Dose enhancement	Electrostatic deposition by applying a potential of up to 1500 Volts is optional for each cell culture separately
Dose monitoring	• Online surface dose monitoring by a Quartz Crystal Microbalance (QCM) in µg/cm². • Integrated sampling probes in the reactor for aerosol measurements a for example SMPS, FTIR, filter …
Automation / Quality insurance	Integrated standard routines for leak tests, exposure experiments and more with comprehensive data acquisition
Dimensions	1923 x 1855 x 649 (H x W x D in mm) / 480 kg



Mülhopt, Sonja et al. (2016): *Journal of Aerosol Science* 96, S. 38–55.

Setup and Measurement Techniques

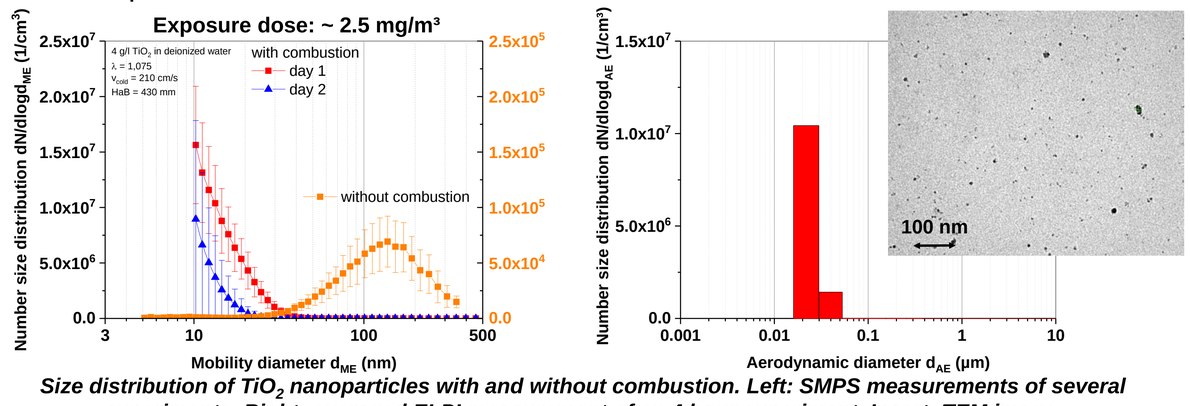


Experimental setup with installed measurement techniques.

1. **Polymer nanocomposite powders** (< 315 µm) or suspensions of pure nanoparticles are aerosolized and added to an Ethylene / Air mixture (λ = 1,075)
2. **Tube burner**: Combustion of the gas/particle mixture
3. **Dilution** of combustion products and comprehensive characterization via physical, chemical and biological measurement techniques
   4. **ELPI**: number size distribution between 10 nm and 10 µm
   5. **Vitrocell® Automated Exposure Station**: exposure of human lung cells at the Air/Liquid-Interface
   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
   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

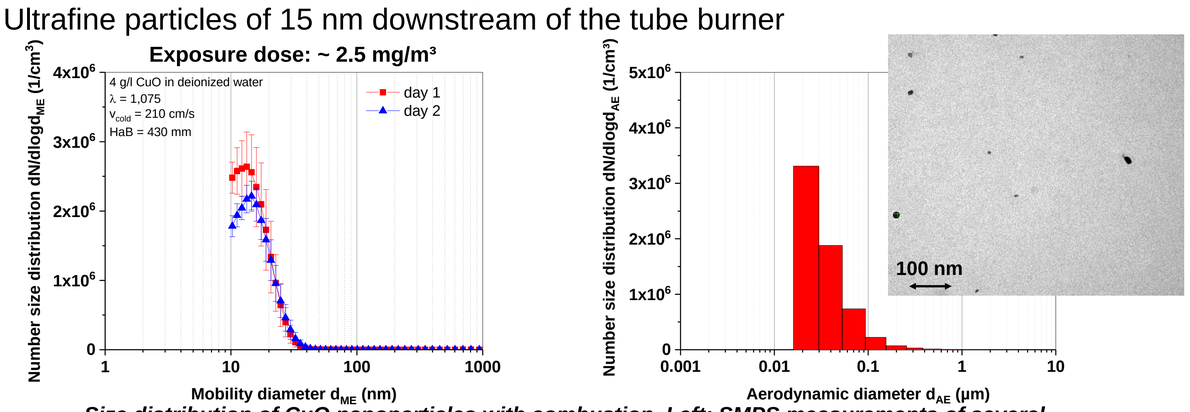
Measurement of Combustion Aerosols

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



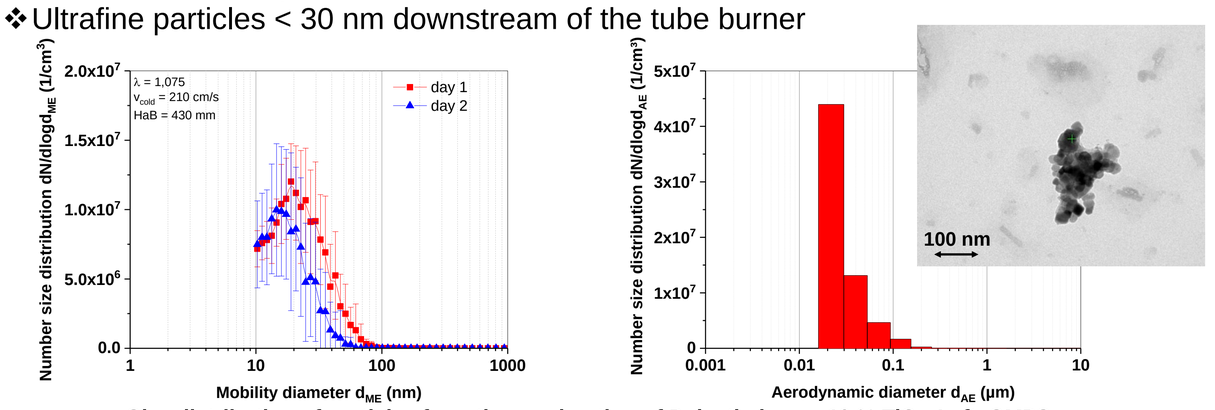
Size distribution of TiO_2 nanoparticles with and without combustion. Left: SMPS measurements of several experiments. Right: averaged ELPI measurement of an 4 hour experiment. Insert: TEM image.

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



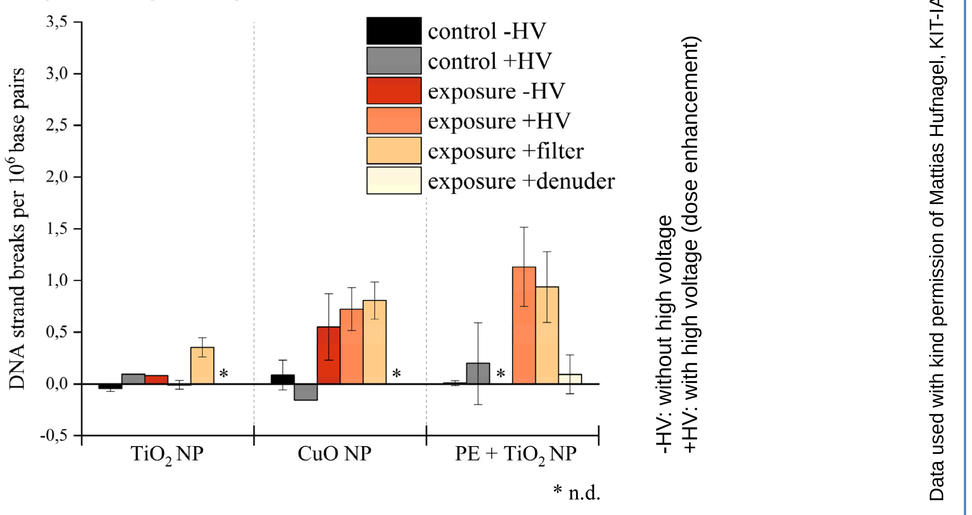
Size distribution of CuO nanoparticles with combustion. Left: SMPS measurements of several experiments. Right: averaged ELPI measurement of an 4 hour experiment. Insert: TEM image.

- The **Polyethylene + 10 % TiO_2** nanocomposite is tested in comparison to the pure nanoparticles and pure matrix
- Ultrafine particles < 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 (Control: Humidified synthetic air, filter: precipitation of particles, denuder: precipitation of volatile organic compounds).

Conclusions

- Succesful application of the illustrated measurement chain
- Comprehensive characterization of the combustion aerosol of nano-enabled thermoplastic
- 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

CONTACT
Dr. Wolfgang Becker
Fraunhofer ICT
www.ict.fraunhofer.de
wolfgang.becker@ict.fraunhofer.de

The project is part of the funding initiative NanoCare of the German Federal Ministry of Education and Research
Grant No. 03XP0009

SPONSORED BY THE
Federal Ministry of Education and Research